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LOOK AROUND! WHAT CAN YOU DISCOVER?

The science center - a critical space for science student teachers' development

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ABSTRACT

This thesis aims to examine the opportunities and constraints on student teachers' learning of science and teaching science when they work in small groups; planning, implementing, and reflecting upon teaching at the science center. In addition to this aim, this thesis seeks to identify what becomes critical for teacher educators and science center educators when facilitating experiences that enable student teachers to learn, teach, and integrate science didactics theories into practice.

Several studies indicate that science student teachers face challenges when it comes to developing science knowledge, and teaching science. Furthermore, they have limited opportunities to integrate their knowledge into practice in addition to their internship at schools. A body of research demonstrates that practicing science teaching in various out-of-school science environments, e.g., science centers, science museums, botanical gardens, and aquariums, offers many learning opportunities for student teachers. What is distinctive about this thesis is that it examines student teachers' practice at the science center from a subject-specific didactic perspective. This means that it focuses on *how* student teachers handle different aspects of teaching and learning science when they plan, implement, and reflect on their lessons at a science center. Thus, in this thesis, a special consideration is given to contextual aspects of the science center environment and how student teachers act upon its affordances.

The educational context of this thesis is a course module for student teachers in science and technology. The module was developed by teacher educators at the University of Gothenburg and science educators at the Universeum science center in Gothenburg and involves becoming familiar with the science center's exhibitions, as a context in which to plan, implement, and reflect upon short lessons with invited students from schools. The empirical data in the first and second study comprises of video footage focused on student teachers' planning meetings and implementation of the science lessons at the science center. The third, and fourth study, in the thesis are based on 'video-stimulated reflection interviews' with the same student teachers after they have completed the course module at the science center. In order to analyze the complexity of aspects in science didactics that comes to the fore in the student teachers' practice, the theoretical frameworks, variation theory, theory of affordances, and theories of reflection are used.

The results of this thesis strengthen the notion that an out-of-school science environment, such as a science center, can play a significant role in student teachers' knowledge development in science didactics. However, the thesis highlights the importance of iterative educational opportunities where student teachers can (1) create and reflect on didactical situations and their teaching's relevance structure for the intended group of students, (2) develop representational tools to help students connect the macroscopic and (sub) microscopic worlds of science, (3) discern the possibilities and limitations of the exhibitions in relation to an intended science content, and (4) develop their responsiveness to students' interactions with the environment and how these interactions can be captured in 'teachable moments'. The thesis contributes with knowledge of how a didactic model, the didactic tetrahedron, can be used as a tool for student teachers and teacher educators when planning and analyzing didactical situations. Furthermore, in relation to methods, this study demonstrates the ways in which video-stimulated reflection can be used for discussing issues of science didactics, and challenges of integrating theories of teaching and learning in practice in a science environment beyond the classroom.

SWEDISH ABSTRACT

Syftet med denna avhandling är att undersöka vilka möjligheter och begränsningar ett vetenskapscenter innebär för lärarstudenters kunskapsutveckling när de i mindre grupper planerar, genomför och reflekterar över sin undervisning på ett vetenskapscenter. Ytterligare ett syfte är att identifiera vad som blir kritiskt för lärarutbildare på universitet och science centret när det gäller att möjliggöra utveckling av lärarstudenters förståelse av naturvetenskap och att integrera ämnesdidaktiska kunskaper i undervisningen.

Forskning visar att lärarstudenter möter utmaningar i att både förstå naturvetenskapliga idéer och teorier och att undervisa i naturvetenskapliga ämnen. Vidare visar studier att det i lärarutbildningar ges för få möjligheter att pröva sina kunskaper i praktiska undervisningssituationer, utöver den verksamhetsförlagda utbildningen. Det finns dock flera studier som visar att miljöer så som vetenskapscenters, naturhistoriska museer, botaniska trädgårdar och akvarier kan erbjuda många möjligheter för lärarstudenters utveckling. Det som är utmärkande för denna avhandling är att den undersöker lärarstudenters möjligheter till utveckling av ämnesdidaktiska kunskaper i en vetenskapscenterbaserad center miljö. Det innebär att den fokuserar på hur lärarstudenter hanterar olika aspekter av undervisning och lärande när de planerar, genomför och reflekterar över lektioner på ett vetenskapscenter. I avhandlingen beaktas särskilt kontextuella aspekter som berör miljön och hur lärarstudenter erfar dess handlingserbjudande.

Avhandlingen utgår från en lärarutbildningskontext där lärarutbildare vid Göteborgs universitet och pedagoger vid Universeum science center tillsammans utvecklat en kursmodul. Modulen syftar till att erbjuda lärarstudenter en möjlighet att bekanta sig med en lärmiljö utanför skolan och undersöka möjligheter till undervisning och lärande i naturvetenskap och teknik. I kursmodulen ingår att, i mindre grupper planera och genomföra lektioner med inbjudna skolklasser. Det empiriska materialet i den första och andra studien i avhandlingen baseras på videoinspelningar av lärarstudenters lektionsplaneringar och genomförande av lektioner i naturvetenskap på vetenskapscentret. Den tredje och fjärde studien i avhandlingen bygger på s.k. videostimulerad reflektion med samma lärarstudenter efter att de har genomfört undervisningen på vetenskapscentret. För att analysera den komplexitet som ämnesdidaktisk kunskap utgör och som har betydelse i lärarstudenternas praktik, används olika teoretiska ramverk, varvid de mest primära är variationsteori och teorier om handlingserbjudande och reflektion.

Resultaten i denna avhandling stärker uppfattningen om att en miljö utanför skolan, så som ett vetenskapscenter, kan spela en betydande roll för lärarstudenters ämnesdidaktiska kunskapsutveckling. Dock visar avhandlingen på att flera och återkommande utbildningstillfällen behövs där lärarstudenter får (1) skapa och reflektera över didaktiska situationer och undervisningens relevansstruktur för den tänkta elevgruppen; (2) utveckla en förståelse för användning av olika representationsformer för att hjälpa elever att koppla mellan den makroskopiska och (sub)mikroskopiska världen; (3) urskilja utställningarnas möjligheter och begräsningar kopplat till lärande av ett tänkt naturvetenskapligt innehåll; (4) utveckla deras lyhördhet för elevers interaktioner med miljön och hur dessa kan fångas upp i undervisningen. Avhandlingen bidrar med kunskap om hur en didaktisk modell i form av en tetraeder kan användas som verktyg för lärarstudenter och lärarutbildare vid planering och analys av didaktiska situationer. Vidare hur videostimulerad reflektion kan utgöra en meningsfull metod för att synliggöra ämnesdidaktiska aspekter i undervisning av naturvetenskap och utmaningarna med att integrera teorier om undervisning och lärande i en lärmiljö utanför klassrummet/på ett vetenskapscenter.

Summer´s proselytizing rains and sunny days - convert our fields of rape from winter's lime green to illuminating lemon yellows.

Grey geese have landed, coots have moved on.

The nights are sinking into the abyss of white, blue-white, and black shadows of sunless, neither nor something in between night and day.

Embraces Vincent

LIST OF PAPERS

I. **Student teachers' collaborative learning of science in small-group discussions.** Thorén Williams, A., & Svensson, M. *Published online in Scandinavian Journal of Educational research, 07 July 2020.*
 https://doi.org/10.1080/00313831.2020.1788141

II. **Affordances of a living rainforest exhibit for student teachers' enacted curriculum narrative about ecosystems.** Thorén Williams, A., Hansson, Ö., & Sanders, D., *Manuscript to be submitted.*

III. **Growing student teachers' reflective practice: explorations of an approach to video-stimulated reflection.** Thorén Williams, A. *Published online in reflective practice, 07 September 2020.*
https://www.tandfonline.com/doi/full/10.1080/14623943.2020.1798917

IV. **Student teachers' challenges with science didactics when teaching at a science center.** Thorén Williams, A., Svensson, M. *Manuscript to be submitted.*

PREFACE

In 2011 I began a new journey, from being a science teacher in upper primary school and lower secondary school, to becoming a science educator at the Universeum science center in Gothenburg. It was a significant change to leave a well-known classroom and enter another educational context, of a completely different nature, beyond school. Unlike school, I experienced this new workplace as associated with positive expectations on science as fun and exciting – a place encouraging free-choice explorations and hands-on science. In my work with programs for students on school visits, the aim was to awaken students’ interest in science and technology. After a few years of developing and implementing school programs, I transferred to working with continuing training in science, technology, and sustainable development of teachers in preschool to secondary school. In this work, teachers were asked about how the science center could be a resource in their professional practice. Frequent teacher responses concerned the need for support and deeper knowledge of using the exhibitions for teaching and learning specific curriculum topics in science and technology. Although the teachers found the environment exciting and triggering their students' curiosity, they experienced it as challenging compared to the classroom. In addition to working with continuing training of teachers, I had the opportunity, in 2014, to collaborate with teacher educators at the University of Gothenburg. The project aimed to develop a course module for student teachers, in which they were given the task to plan, implement, and reflect on short science lessons with school students at the science center. In my work with the student teachers, I learned that teaching and learning science at the science center poses challenges to the student teachers beyond teaching in the classroom, which I found interesting. Thus, it is in this educational context my doctoral project took its point of departure in 2015. In the very beginning of that journey, I was interested in investigating both experienced teachers’ and student teachers’ practice of planning and teaching science lessons at the science center. However, at an early stage of the research project, I decided to focus on student teachers only and their learning of science and teaching science in small groups. Hence, I became deeply interested in following their work and development in science teaching. This research journey has made visible the complex web of didactic aspects student teachers have to consider in their training.

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1 INTRODUCTION

This thesis aims to shed light on the ways in which out-of-school environments, such as a science center, becomes a critical space for student teachers to learn science and integrate their understanding of science and science didactics in practice beyond the classroom. Furthermore, the thesis contributes with knowledge of what becomes critical for teacher educators and science center educators when facilitating experiences that enable student teachers to learn, teach, and integrate theories of science didactics in an unfamiliar, resource-rich, and multi-sensory environment.

1.1 Context and rationale

A growing body of research suggests that cooperation with out-of-school science environments, for example, science centers, science museums, and botanic gardens, "could strengthen teacher education programs and provide them with an invaluable resource where theories about teaching and learning could be merged with practice in a novel, resource-rich context" (Gupta & Adams, 2012, p. 1147). Research demonstrates that by integrating out-of-school science environments, e.g. aquariums, science museums and nature centers in science teacher education, student teachers are offered unique opportunities for learning science and teaching science (Avraamidou, 2014; McGinnis et al., 2012). A central notion in teacher education is that student teachers have recurring opportunities to practice planning and teaching in the classroom and outside. It is equally important that they be given the opportunity to reflect on their teaching together with fellow students and teacher educators (Beauchamp, 2015). There is a criticism that student teachers are offered too few coherent opportunities during their training to link theories of learning and teaching encountered in coursework to practice (Darling-Hammond et al., 2005; Hammerness & Klette, 2015; Jenset et al., 2018) and there is also a call for finding new ways of preparing science teachers, which links the specific course work to practice science beyond the classroom (Adams & Gupta, 2017). Thus, there is an issue of linking theory to practice on different levels. The approaches to integrate out-of-school science environments in teacher students preparation, which this thesis reports on, is a way to respond to the need for science student teachers to connect their understanding of theories of teaching and learning science to practice and vice versa.

In their review, McGinnis et al. (2012) found that practicing in out-of-school science environments increased student teachers' positive attitudes, interest in science and science teaching – as well as their confidence as science teachers. In addition to these benefits, the student teachers could develop new teaching methodologies, expanding teaching experiences and opportunities to reflect (McGinnis et al., 2012). In a study by Gupta and Adams (2012), three different partnerships between science museums and teacher educations were examined. The results demonstrate that student teachers had the opportunity to see different styles of teaching, reflect upon themselves, and experiment with pedagogical strategies when teaching the same topic to visitors of all ages and background. In more recent studies by Avraamidou (2015) and Adams and Gupta (2017), student teachers developed their identity as science teachers and teacher agency while practicing science teaching in the various settings of an out-of-school science environment. Adams and Gupta (2017) describe teacher agency as “those with confidence in their abilities to access and appropriate resources at hand (and to acquire or, more often than not, re-create resources that are not immediately available) to meet their needs, as teachers, of teaching diverse learners” (p. 135).

The Universeum science center that constitutes the site this thesis, is located in the central parts of Gothenburg. In contrast to the more traditional science centers (Tlili et al., 2006), it houses both a selection of live animals and plants (from various regions of the world) and more typical exhibitions about space discoveries, experimental workshops and traveling exhibitions. A more detailed description of this science center is outlined in Chapter 4.

Through the work with in-service teachers at the science center, it became interesting to gain a deeper understanding of the challenges they face when teaching science topics to their students in the different exhibitions. This interest grew larger in connection with a collaboration project with teacher educators at the University of Gothenburg. The project began in 2014 and resulted in a course module, which is now a permanent feature in two teacher training programs. One of the programs is a four-year-long training program of student teachers preparing for teaching science in primary school (age of students, 6-12 years). The other is a one-year training program for student teachers preparing to teach science subjects in secondary school (age of students, 13-19 years). The latter category of student teachers have a university degree in science and/or engineering. The structure and content of the course module are the same in the two programs and aim to give student teachers opportunities to explore the potential of the science center for teaching and learning science, becoming familiar with the exhibitions and, in small groups, plan and implement short science lessons with invited students. The course module also involves reflection upon practice, individually and collectively, at the science center.

From my work of facilitating and observing student teachers’ practice at the science center, several aspects of understanding science and teaching science seemed to be challenging. These aspects concern the student teachers’ knowledge of science ideas and principles that they intend to teach about, their knowledge of students’ experiences of science education, and knowledge of the science center environment. It also involves the discernment of phenomena in the science center exhibitions and relating them to explanatory models encountered in school and teacher education. These observations are supported by Rietveld and Kiverstein (2014), who found that when an environment is new to learners, they may perceive a more limited range of action opportunities than experienced people working within this context. In addition to these challenges, an abundance of material-richness and provision of multi-sensory experiences seem to obscure the variation, for example, the variety of plants (Nyberg et al., 2019) that is relevant for the student teachers to perceive in order to teach specific science content. From my experience of working with student teachers at the science center, these challenges may not appear at first. However, they become tangible to student teachers as they in small groups, plan, teach, and evaluate their teaching.

As much as planning, implementing, and reflecting upon practice in the science center offers a range of learning opportunities professionally and personally, it may also constrain student teachers' opportunities to understand science and teach science in ways that are conducive to students’ learning. In contrast to teaching in the classroom, where the teacher can select and decide how to use different (familiar) material resources to make the science content accessible for the students, the explanatory models and objects (living and non-living) in the science center are selected and presented by others to bring about specific experiences. These selections are also limited in scope and represent only certain science ideas and principles, which can restrict student teachers’ opportunities to extend their science knowledge and content for teaching (McGinnis et al., 2012). In addition, the less controllable environment of the science center may influence teaching-learning situations in unpredicted ways, both contributing to learning through sensory experiences and hands-on interactions with the environment - as well as disrupting and taking the attention away from what may be the intended focus in teaching.

Other constraining aspects of student teachers’ learning, which McGinnis et al. (2012) found in their review, is the short time period student teachers were allowed to practice in the out-of-school science environments and the difficulty to transfer and use new teaching strategies gained in these environments. It appears that the less controllable science center's physical environment and its provision of multi-sensory experiences extend the complexity of contextual affordances beyond the classroom.

Many of the previously mentioned studies on integrating out-of-school science environments in science teacher preparation demonstrate that student teachers develop knowledge in science and science teaching in these environments (McGinnis et al., 2012). However, their primary focus appears to be on the affordances of these sites for developing teacher identity, agency, and reformation of one's beliefs about science and science teaching, particularly, through the interaction with the exhibitions (and its objects) and the diversity of visitors as learners. However, few studies have focused on how student teachers, in small groups, try to understand a specific content, intended for teaching, and how they treat this content in relation to the material resources of the environment, and specific groups of students. In this thesis, the aim is to contribute with a didactic research perspective that holds an interest in the specific knowledge of how to 'unpack' or open up a particular science content in a way that enables the (school) students to make meaning of the particular content (Hopmann, 2007). In the European and Scandinavian educational tradition, didactics is viewed as teachers' professional science, as well as the individual knowledge teachers possess and use in their practice (Osbeck et al., 2018). Thus, didactics is not just an academic research discipline, but also an essential knowledge area for teachers in planning and analyzing teaching. In the Swedish teacher education it is, therefore, central that science student teachers develop the subject-specific area of didactics: science didactics (Andersson, 2011). School subjects, such as chemistry, physics, and biology, are closely related to their characteristics as disciplines and didactical considerations in teaching, and can therefore be grouped, as science didactics (Kansanen, 2009).

According to one of the basic didactic models, the teacher must start with the students and ask questions such as who are my students? And what do they know? Furthermore, what should the teaching contain and how should this content be made accessible for the students? And why should certain content be taught in a certain way? (Andersson, 2011). In addition to these aspects of didactics, the teacher's own subject knowledge is of course also important (Ball et al., 2008; Rollnick et al., 2008; Zetterqvist, 2003). In case of the material-rich and multi-sensory context of the student teachers' practice, it is just as central to ask the question: how should the environment be handled in teaching? All of these didactical questions can be said to frame a didactical situation (Brousseau & Balacheff, 1997), in which student teachers arrange the interplay between the science content, the material and sensory resources of the science center environment (objects and living animals and plants – as well as sound, temperature, humidity etc.), and the school students (Nyman, 2017; Rezat & Sträßer, 2012).

1.2 The overall aim and subordinate research questions

As the above introduction indicates, there is a complex web of aspects in science didactics that student teachers must handle in their practice at the material-rich science center. In addition, given the gap in research on student teachers' integration of theories in science didactics with practice, the overall aims of this thesis are formulated as follows:

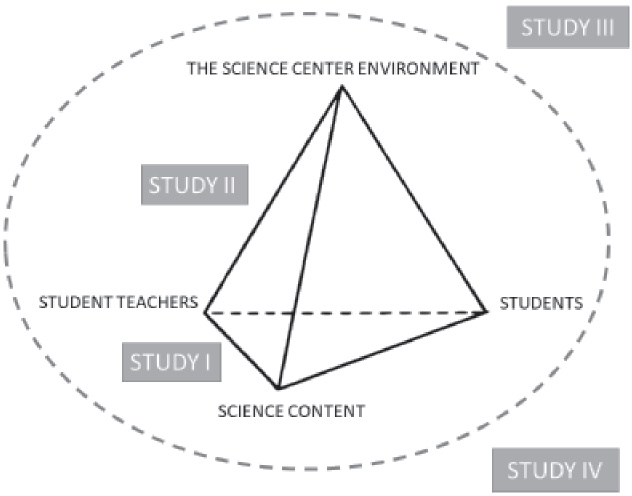
(1) Learn more about the opportunities and constraints on student teachers' learning of science and teaching science when they in small groups plan, implement and reflect upon teaching at the science center.

(2) Identify what becomes critical for teacher educators and science center educators when facilitating experiences that enable student teachers to learn, teach, and to integrate theories of science didactics in an unfamiliar, resource-rich, and multi-sensory environment.

(3) Contribute to understanding how the science center can be a critical space for student teachers' development.

To address this thesis's aim, the didactic tetrahedron, initially developed by Rezat and Sträßer (2012) and further adapted by Nyman (2017), offers a useful model of how different aspects of science didactics that are at play relate to each other when planning and teaching at the science center (see Figure 1). Furthermore, the model foregrounds the four sub-studies and their respective foci and specific research questions. The model thus serves as a frame for the research as a whole and for each study. The connections between the nodes and the triangular surfaces in the tetrahedron constitute areas for analysis (Nyman, 2017) and illustrate the complex web of, in this case, aspects in science didactics that student teachers must handle in their practice. A more detailed description of the didactic model and how it is used as an analytical tool in the fourth study is outlined in Chapter 3.

Figure 1. The figure illustrates how each of the four studies relate to the areas of the didactic tetrahedron, initially developed by (Rezat & Sträßer, 2012), and further adapted by Nyman (2017).



The first study addresses the question: (Q1) *how and to what extent are opportunities for learning science constituted through student teachers' talk in small-group discussions?* The interest is on the relationship between the student teachers and the science content (see Figure 1), the what-aspect of didactical questions. It is about how student teachers, through small group discussions, provide learning opportunities in science for themselves.

The second study addresses two questions: (Q2) *what affordances of the living rainforest do the student teachers act upon in constructing their narrative about the curriculum topic 'ecosystems'? Furthermore, (Q3) in what way does the rainforest appear to afford such teaching actions*? The study is an in-depth examination of how one of the groups of student teachers act upon the material-rich and multi-sensory living rainforest's opportunities (and constraints) in their teaching to students abut ecosystems. This study is primarily foregrounded by the tetrahedron's surface: student teachers - science content - the science center environment (see Figure 1). To some extent, it also concerns the tetrahedron as a whole.

In contrast to the first and second studies, the third and fourth studies involve all of the relationships in the tetrahedron. In these studies, the three groups of student teachers, through video-stimulated reflection, share their concerns and reflect upon the different aspects of their science teaching at the science center. The third study however, focus on the student teachers' reflective process as such and addresses the question: (*Q4) how and to what extent can an approach to video-stimulated reflection interviews facilitate student teachers to create a space for collective experiences to imagine how they would improve their practice?* In this study, the video-stimulated reflection interviews fulfill two functions. On the one hand, it identifies and analyzes reflection; on the other hand, it provides an opportunity for learning through reflection on collective experiences.

The fourth study is based on the same set of empirical material as in the third study but with a different research focus. It addresses the two questions: (Q5) *what are the challenges student teachers experience when teaching science at the science center? Furthermore, (Q6) what aspects of science didactics in these challenges becomes central in creating didactical situations?* In contrast to the third study, the fourth focuses on the content of reflections. It relates to all of the different relationships and surfaces of the tetrahedron (see Figure 1).

2 BACKGROUND

The concept of 'out-of-school learning' was initially introduced by Resnick (1987) to discuss the need for real world experiences to create learning opportunities and enhance students' sense of meaning and relevance. It involves curricular and non-curricular learning experiences for school students and university students outside the school environment. According to Eshach (2007) 'out-of-school learning' can be divided into informal and non-formal learning. In his definition, informal learning is something that happen spontaneously in our daily lives, while non-formal learning takes place in institutions, such as science centers, museums, and organizations, and share characteristics with formal learning (in schools), but with the difference that learning comes from intrinsic motivation. These ideas of learning are problematic. Firstly, learning is learning (Dierking, 1991, p. 4), regardless of place, time, inner or external motivation, but above all, learning is connected to learning something (Marton, 2015; Marton & Booth, 1997). Secondly, when the out-of-school science environment becomes a place for formal science education, whether at the university or in schools, there is an underlying curriculum with specific goals, and certain expectations on the teachers and learners. Although school visits may involve free choice explorations (Rennie, 2016), the teacher often has certain intentions and expectations on the students. In the educational context that thesis reports on, learning is indeed intentional and governed by different (formal) curricula – the one that governs their own training and the one that governs student teachers' science education. These circumstances entail an approach to teaching and learning of which the activities are informed by different prescribed curricula and are highly embedded in a formal educational context. With this said, this thesis does not differentiate between different types of learning. Still, it recognizes the difference between formal and informal as to whether there is a set of specific targets to aim for, assessment requirements, and particular content elements. Since the student teachers' teaching and learning science takes place outside the university and school, in this case a science center, the term out-of-school science environment will be used as a reference to sites such as a science center and other similar institutions.

2.1 Science centers

Out-of-school environments such as science centers are often described as science-rich environments (Adams & Gupta, 2017; Rodari, 2009) that convey science as fun, personal, as doing, as relevant to everyday life, and as socialization into science citizenship (Tlili et al., 2006). Such environments often have clear goals, although they can be difficult to achieve and measure. A common goal is to influence both children's and adult people's attitudes to science and technology through experiences that create curiosity, increased understanding - as well as offering enjoyment and seeing science as fun (Falk et al., 2007). Thus, science centers' goals rest on the idea that there is a lack of scientific knowledge in society, and by remedying this shortage, interest and curiosity in science can be created. At the same time, these sites want to make science accessible to everyone and not an exclusive area of knowledge for a few (Tlili, 2008).

2.1.1 The Universeum science center

The Universeum science center is located in the central part of Gothenburg. In contrast to the more traditional science centers (Tlili et al., 2006), it houses both live animals and plants from northern part to the southern part of the world. The science center has an aim to awaken visitors' interest and offer experiential learning. When the Universeum science center opened, it wanted to foreground direct experiences instead of having descriptive signs in their exhibitions. An example of this is the sparse information signs in the living rainforest exhibition. However, in the more typical exhibitions, such as the space exhibition, there are both interactive models and explanatory texts. From a pedagogical perspective, the presence or the absence of descriptive signs could pose different challenges. On the one hand, signs can help the learners to understand observations and interactive experiences. On the other hand, signs could be perceived as being in the 'way' of direct experiences (Gunnarsson, 2016). The educational activities at the science center aim at all ages in the school system from preschool to upper secondary school. In addition to school programs, the science center offers professional training for teachers in science and technology and, in this role, cooperates with teacher education at the University of Gothenburg. The course module, which encompasses the context of this research, is one of the collaborations between teacher education and the science center.

2.1.2 Research on teaching and learning at science centers and science museums

Research suggests that thoughtfully designed field experiences make it possible for student teachers to strengthen, use and combine concepts and theories they learn in their coursework (Darling-Hammond et al., 2005). There is a well-recognized view that student teachers learn to teach when engaging in practice together with other learners, particularly, when science content is experienced and used within practice (de Jong et al., 2011; Schneider & Plasman, 2011; Van Driel & Abell, 2010). A way to meet the need for field experiences for student teachers' development, which has proven to be fruitful, is integrating out-of-school science environments (e.g., science centers, science museums, and aquariums) in student teachers' preparation. Studies suggest that such partnership can offer a rich context for student teachers learning (Adams & Gupta, 2017; Avraamidou, 2014; McGinnis et al., 2012; Rennie, 2014). McGinnis et al. (2012) revealed that partnership between out-of-school science environments and teacher education provides opportunities for student teachers to learn science and to practice science instruction while working alongside museum educators. Similar studies show that while student teachers practice science teaching in these various settings, they further develop their identity as science teachers and self-confidence in science teaching (Adams & Gupta, 2017; Avraamidou, 2015; Jung & Tonso, 2006; Katz et al., 2013; Wallace & Brooks, 2015). Avraamidou (2014) found that practicing teaching in an environment with a low level of assessment of themselves and visiting students' learning provides a comfortable and secure educational context that support student teachers to believe on their ability to perform tasks within the practice of teaching. In a study by Kelly (2000), student teachers were assigned to construct curriculum units in combination with inquiry-based science explorations and field-testing with students at primary school level. When student teachers later taught their curriculum units to students, a majority of them were able to explain science concepts. The study shows that the student teachers learned science content, especially when teaching and learning alongside the students. In a similar study by Jung and Tonso (2006), student teachers were assigned to teach at a nature center and a science museum. The student teachers learned a complete lesson plan and then taught it to students in primary school. The findings from the study by Jung and Tonso (2006) demonstrate that the student teachers developed understanding of science ideas with support from science educators. Furthermore, the student teachers were allowed to practice hands-on science, develop their practical skills, and self-confidence by teaching the same lesson repeatedly with different groups of learners. Adams and Gupta (2017) examined student teachers' science teaching with carts (different objects on a trolley for representing big ideas in science) at a natural history museum. Their results demonstrate that student teachers developed teacher agency and teaching identity as science teachers through the interactions with a diversity of learners, the objects on the cart and the content of exhibitions. These experiences, in turn, allowed the student teachers to shift from teacher-centered to learner-centered view on teaching and learning, improvise, capture teachable moments, and imagine their future selves as science teachers in the classroom.

As much as the science museum positively influences student teachers' interest and development in becoming science teachers, they pose contextual and pedagogical challenges beyond the classroom. In research conducted by (Nyberg et al., 2019), a group of primary student teachers was investigated regarding their attention to plants and animals in two different out-of-school science environments. One of the sites was a living rainforest exhibition in a science center (the same science center as in the present study) and the other a greenhouse rainforest in a botanic garden. Although the rainforest in the botanic garden presented plants more explicitly, their findings show that the student teachers at both sites noticed animals more than plants. The authors suggest that in order to avoid "plant blindness" (see e.g., Sanders et al., 2015) in animal rich settings, careful consideration must be made of how sites should be designed to uncover the hidden affordances of plants (Nyberg et al., 2019). Thus, their study mirrors the words of (Norman, 1999) "affordances are of little use if they are not visible to the users. Hence, the art of the designer is to ensure that the desired, relevant actions are readily perceivable" (p. 41). However, it should be noted that an exhibition designer may not have as a primary goal to feature plants, animals or other living or other exhibits in ways that offer teachers pedagogical affordances (including action opportunities – as well as constraints on action).

In a study of teenagers' interest of science and technology in connection with a school visit to a science center, Fors (2012) concluded that there is a "missing link." Teenagers express that they want to make their own interpretations of the exhibits and have the opportunity to contribute to the meaning of an activity. At the same time, they want to develop their social identity (Fors, 2012). Thus, it appears that the 'missing link' may be the lack of a relevance structure for the teenagers, which connects the teenagers' own experiences of the world with the scientific and technological representations of the science center (Lo, 2012; Marton & Booth, 1997). According to Marton and Booth (1997), it is central for teachers to build a relevance structure for their learners, which involves "aspects of the situation that indicate what it is aimed at, what it demands, and where it will lead" (p. 180). In another study, Haraldsson-Sträng (2013) investigated the interaction between teachers and five-year-old preschool students at the same science center as used in this thesis. They found that when the teachers and their preschool students visited the living exhibition, "The way of water" (a model that features Swedish nature from north to south), they did not talk about the same things. What caught the teachers' and the preschool students' attention and became object of discussion, could be completely different phenomena or particularities in the exhibition (Haraldsson-Sträng, 2013). Thus, it appears that the preschool students' interactions with the exhibition implied another relevance structure for the students than the one the teachers might intend. In a study by Achiam et al. (2014), exhibitions in a science museum were investigated with regard to attracting visitors attention without being mediated by another person (e.g., science educator or guide). Furthermore, they investigated how visitors interacted with an exhibit that they had never seen before and how the visitors understood those interactions. The results show that visitors could act upon the exhibit affordances based on what they perceived and that objects in the museum exhibition afforded different kinds of visitor actions, depending on the ways in which museum objects were displayed (Achiam et al., 2014). Although that study focused on every-day-visitors to a natural history museum, the findings are applicable to the student teachers in the present study. Like the everyday visitor, the student teachers act upon affordances of the science center exhibitions based on what they can perceive and can judge as relevant for their teaching specific science curriculum topics to an intended target group of students.

The aforementioned studies point to some challenging aspects of teaching and learning in out-of-school science environments. The teachers (and perhaps science center educators) and their learners seem to perceive different things in the material-rich exhibitions and act upon the affordances accordingly. Furthermore, teachers seem to have difficulties bridging the gap between their own experiences of the exhibitions, the learners' experiences, and building relevance structure for their learners (see section 3.1.1 below).

2.2 Student teachers' understanding of science and science teaching

Teacher education has an important task when it comes to educating knowledgeable and committed teachers in science. In society, academia, and business, the difficulty of attracting young people to science and technology educations is a recurring discussion. Research shows that what the teacher does is the single most crucial factor for students to achieve the expected learning goals (Baumert et al., 2010; Hattie, 2003; Van Driel & Abell, 2010). This means that teachers' knowledge and their ways of making use of their knowledge in practice is of great importance for what students learn in the classroom (Jenset et al., 2018; Shulman, 1987; Zetterqvist, 2003). However, science student teachers seem to encounter difficulties in learning science and learning how to teach science (Korthagen et al., 2006; Schneider & Plasman, 2011; Vikström, 2014). Studies demonstrate that the challenges are related to developing knowledge about science ideas and principles, the nature of science, understanding of the educational context, and learners' needs (Osborne & Dillon, 2008). They are also linked to attitudes and confidence in science teaching (Avraamidou, 2014). One of the difficulties is that student teachers tend to see ideas and principles in science as permanent and unchangeable, rather than as an ongoing human endeavor to understand the world we live in (Nilsson & Driel, 2011). Furthermore, research shows that student teachers in some areas of science have the same level of understanding of science ideas as their future learners (Schneider & Plasman, 2011). Harlen (2015) assumes that the reasons for this might be the student teachers' limited experiences of science-related activities, such as inquiry education, and limited opportunities to develop an understanding of big ideas of and about science during their schooling. The aim of directing teaching and learning towards a limited set of big ideas in science education is to enable an understanding of

> …the world and our experiences in it, rather than a series of disconnected items of knowledge. Building connections and recognising patterns enable learners to identify significant aspects when trying to understand new situations. (Harlen, 2015, p. 5)

It is not simply about student teachers being able to understand the big ideas in science, but about the time they need to discuss them and that teacher education is aimed at the areas around which students have had difficulty developing an understanding (Harlen & Holroyd, 1997). In sum, to meet the challenges student teachers face in learning science; teacher educators need to use student teachers' current understandings of big ideas of and about the nature of science to build new and more powerful ways of learning (Darling-Hammond et al., 2005; Harlen, 2015; Marton, 2015). This may be particularly important for student teachers preparing for primary school that have to develop understanding of the big ideas of science at the same time, as they are to understand their future learners' understanding and development of big ideas.

A large body of research indicates that teachers – as well as student teachers', knowledge and beliefs about science and science teaching has a major impact on all aspects of their practice (see e.g., Forbes & Davis, 2008; Kind, 2016). When student teachers begin their training, they have a picture of what teaching and learning in science is (Schneider & Plasman, 2011) and these pictures are often based on their observations of science teaching from when they were young learners (Darling-Hammond et al., 2005). Although such experiences may be beneficial for the student teachers' attitude towards science teaching, they also are built on the view that science teaching is straightforward, which contradicts the notion of teaching as a complicated activity (Schneider & Plasman, 2011). In addition to personal experiences and convictions of how science teaching should be conducted, teaching traditions among (future) colleagues in schools frame student teachers' intentions in planning and analyzing science teaching (Wallace

& Priestley, 2017). In a study by Kind (2016) on upper primary student teachers' knowledge and beliefs about science teaching, she found that the dominant understanding was to tell, explain, and ask student questions about the science content. This orientation is shown to be connected to naive beliefs about science, which, for example, holds scientific inquiry as generating evidence-based and objective facts established by a single scientific method, and detached from sociocultural circumstances (Kind, 2016). Brown et al. (2013) reports similar findings in a previous study on biology student teachers preparing for secondary school. The student teachers' knowledge and beliefs of science teaching appeared to be dominated by the view of science teaching as telling. This view seemed to be deeply rooted and difficult to change, which, in turn, influenced the student teachers' understanding of, and pedagogical approach to specific science content. The author concluded that teacher educators should allow time and space for student teachers to reflect upon their views on science teaching and support their process of shifting from a teacher-centered way of teaching (e.g., telling, transmitting, and explaining science) to an approach which takes departure from the learners' needs and understanding. Kang et al. (2013) suggest in a study on student teachers' progress and challenges in learning to teach science with an inquiry approach that "teacher educators and preservice teachers could both benefit from explicit opportunities to navigate the border between learning and teaching science" (p. 445). Such studies highlight the problem of student teachers' own experiences of science education teaching during schooling, but they also indicate that there is an issue of how teachers interpret the formal curriculum; viewing the formal science curriculum as an 'order of content to be delivered' seems to induce teaching as telling (Doyle & Carter, 2003).

2.3 Didactics, science didactics and didactic models

As discussed earlier, research indicates that science student teachers require opportunities to develop understanding of different areas and consider a range of aspects when planning, implementing and reflecting/analyzing their teaching. This professional understanding can be referred to as didactics and is recognized as teachers' professional science (Osbeck et al., 2018; Wickman, 2018). In the Scandinavian and northern European countries, didactics is both a field of research and a knowledge base for teachers in their practice of planning lessons and analyzing teaching and learning (Wickman, 2018). The term 'didactics' is a translation of the German term *die didaktik,* and should not be mistaken for the negative connotation of transmitting knowledge (Kansanen, 2009). Contrary to this, a didactic process aims to open up a world for the student (Hopmann, 2007). Within the didactic tradition, there are subject-specific didactic specializations, and each of these can be viewed as the intersection between general didactics and a subject, aiming at arriving at an optimal way to teach and study a particular subject. Sjöström (2018) suggests that the central focus of didactics should be anchored in subject knowledge, practice, theories in didactics, and basic educational science.

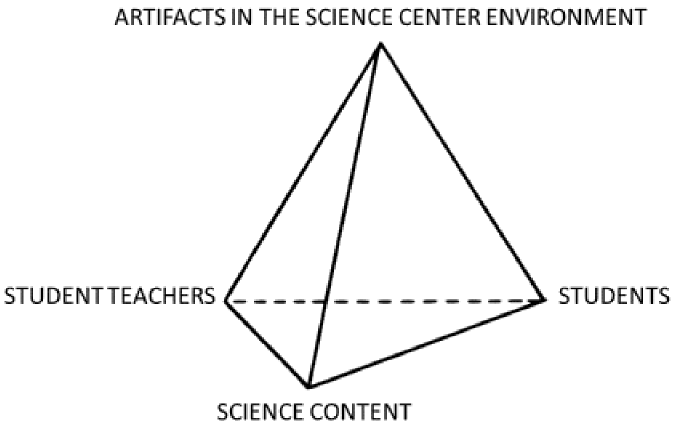
The interest in this thesis is the subject-specific didactics or subject-matter didactics of science education, which is science didactics (Andersson, 2011). Science didactics concerns the particular knowledge of teaching and learning science subject areas, for example, chemistry, physics, and biology (Kansanen, 2009; Zetterqvist, 2003).

Subject-matter didactics is in many ways similar to the American educational term, pedagogical content knowledge, introduced by Shulman (1986, 1987). Both concepts rest upon the idea that teachers require certain knowledge of how to 'unpack' or open up a particular content in a way that enables their students to make meaning of the particular content (Hopmann, 2007). Although, pedagogical content knowledge is in many ways similar to subject-matter didactics, it is narrower in its scope in terms of its connection to school subjects (Zetterqvist, 2003). Shulman's 'knowledge base for teaching', which consists of a number of knowledge areas for teaching including pedagogical content knowledge, arise from the so-called curriculum tradition (Hudson, 2002, 2007). According to Hudson (2002), didactics is "a tradition of thinking and studying teaching and learning" (p. 44), and it raises essential questions of pedagogics, which the curriculum tradition does not. In the 'curriculum' tradition, the curriculum indicates not only what the teacher should teach about, but it also provides templates of what methods to use in teaching and how to organize students' work in the classroom (Hudson, 2007). In the Scandinavian tradition of didactics, the formal curriculum describes the intention and core content of a subject, which the teacher interprets and enacts in the way she or he find relevant and conducive to students learning (Sjöberg, 2018). Thus, the didactic tradition views the teacher as an autonomous, reflective practitioner, and "teaching is not a technical, but rather an interpretative issue, i.e. an issue to be considered in the light of a pedagogical situation." (Hudson, 2002, p. 46). Another difference between the two traditions is that the models in the American and Anglo-Saxon tradition have mainly been developed and used by researchers to analyze teaching (Kansanen, 2009). In the didactic tradition, the models and the work of modelling are just as important as tools for teachers in their practice of planning, analyzing teaching, and learning in the classroom (Jank & Meyer, 2006; Wickman, 2018). Thus, there is a crucial link between didactics and the school subject, which teachers need to understand and master (Kansanen, 2009). However, in subject-matter didactics, the purpose of teaching is not to have students master the content prescribed in the formal curriculum, "but rather the question if and how the educative substance could be opened up for the students as intended; more exactly, if and how it became open in their individual meeting with the content in the given teaching process." (Hopmann, 2007, p. 117). It is about the teachers' ability to integrate theories and experiences of teaching and learning in practice that is conducive to their students (Hammerness & Klette, 2015; Helldén, 2009; Jenset et al., 2018). With this said, subject-matter didactics offers not only models for researching, planning and analyzing teaching and learning in the different educational contexts, but a language for teachers and researchers to communicate didactical issues of concern for teaching and learning particular subjects within their practice (Osbeck et al., 2018; Wickman, 2018).

2.4 Towards a didactic model for analyzing and designing teaching

As mentioned in the previous section, didactic models do not only help teachers in their planning, implementing and analyzing lessons, they are also a central part of research in subject-matter didactics and practice (Wickman, 2018). In this thesis introduction (section 1.1), some of the basic didactic questions were presented (Who are my students? What do they know? What should the teaching contain? How should this content be made accessible for the students? Why should certain content be taught in a certain way?). These questions form one of the basic didactic models for designing teaching (Andersson, 2011). In addition to these didactical questions, the aspect of *where,* the space, in which the teaching and learning is situated, was raised. This aspect concerning the physical context is central when planning and teaching in out-of-school environments where teaching aims to make use of the material resources and multi-sensory experiences to facilitate students' learning and interest. This aspect of science didactics is considered in this thesis from both a research perspective – as well as teacher educator and student teacher perspective. The didactic tetrahedron presented in the introduction (Chapter 1), is in the following further described and how it will be used as an analytical tool for analyzing teaching in this thesis.

Figure 2. The figure shows a modified model of the tetrahedron based on one initially developed by (Rezat & Sträßer, 2012) and adapted model by Nyman (2017).



The tetrahedral model was initially developed by Rezat and Sträßer (2012) and adapted by Nyman (2017) in her research on school students' interest and engagement in mathematics (see Figure 2). The model offers a three-dimensional framework of an undividable system, in which the teacher, through orchestrating the interplay between the students, the subject content, and the artifacts (e.g., textbooks or other materials) creates a didactical situation. Thus, by adding a fourth vertex to the more familiar didactic triangle (teacher-student-subject content) and to the didactical situation that teachers aim to create in teaching (Brousseau & Balacheff, 1997), the tetrahedron also addresses the role and influence of the material resources (Rezat & Sträßer, 2012).

In order to make the model work within the context of this thesis and science education, the nodes of Nyman's model (2017) had to be modified. The node mathematics is replaced with science content and the node teacher is replaced with student teachers. Furthermore, the vertex, artifacts, which in Nyman's model refers to material resources as textbooks in mathematics or mathematical tasks, is in this context referred to both non-living objects as well as living plants and animals in the science center's exhibitions (see Figure 2). According to Rezat and Sträßer (2012) these so-called artifacts are cultural tools and considered as actors that influence, and shape, didactical situations in teaching and learning. Since these artifacts often are shared in the classroom, it is possible to consider them as ‘actors’ that influence and shape learning situations as a whole (Rezat & Sträßer, 2012). However, the idea of artifacts as mediators has its roots in a sociocultural perspective on learning, in which human-made objects and language are viewed as cultural tools that mediate reality (Säljö, 2000). To use the notion of artifact in the analysis of the student teachers’ practice, it needs to include more than human-made objects, such as living plants and animals that constitute a significant part of the science center's exhibitions. This expansion of the concept is not unproblematic. Natural objects and living organisms are in the pure sense not cultural tools. However, the science center is not a natural environment but a presented world (Braund & Reiss, 2006), in which the exhibitions are human-designed spaces where the human-made objects, natural objects, and living animals and plants are placed. This is done to represent certain phenomena (e.g., a South American rainforest) or science ideas and principles (e.g., the law of gravity). Furthermore, when these resources are used in science teaching and learning, the teachers (and learners) ‘instrumentalize’ them as representations (Béguin & Rabardel, 2000; Rezat & Sträßer, 2012). With this view on artifacts, they do not only include human-made but also the science centers’ living exhibitions with their plants and animals. The didactic tetrahedron is used as a research frame of the thesis as a whole and in the fourth study (see Paper 4), to investigate student teachers’ challenges of creating didactical situations when teaching at the science center. That is, the difficulty of arranging the interplay between the science content, students, and the artifacts. How the didactic model is used in the analysis in the fourth study is described in more detail in the Chapter 4.

3 THEORETICAL POINTS OF DEPARTURE

As described in the previous chapter, the relationships between the four nodes of the didactic tetrahedron, building triangular surfaces connecting to each other, illustrate the complicated web of aspects of science didactics and constitute areas for analysis (Nyman, 2017). Therefore, the didactic tetrahedron can function as a useful model to foreground this thesis's aim to learn more about the opportunities and constraints on student teachers' learning of science and teaching science when they in small groups plan, implement, and reflect upon teaching at the science center. The model delimits, and links together, the four studies and choices of theoretical frameworks. Thus, the didactic tetrahedron helps structure the theoretical points of departure for this thesis.

The theoretical framework constituting the foundation of this thesis is variation theory (Marton, 2015), which is a theory of teaching and learning. The second theoretical framework consists of the theory of affordances (Gibson, 1986) and is used to examine the ways student teachers act upon the opportunities and constraints of the science center environment and its objects. The third theoretical framework concerns reflection and is used to identify and describe the student teachers' reflective process (Schön, 1983, 1987) when viewing video footage of their teaching. Complementary frameworks support each theory. In addition to variation theory, the Bungum et al. (2018) notion of small-group discussions is used. Bruner's notion of narrative - making in teaching (Bruner, 1991) and the concept of multiple external representations (MER) (Tsui & Treagust, 2013) complements the theory of affordances. Finally, the reflective cycle model (Lee & Loughran, 2000; Mackinnon, 1987) accompanies Schön's notion of reflection and reflective practice.

The chapter begins with an outline of variation theory of learning in section 3.1, which lends its principles and perspective on learning to this thesis on two levels. On one level, the theory contributes to the principles of powerful teaching, in this case, with principles of what teacher educators need to do in the particular situations, for the student teachers and in relation to specific objects of learning. It therefore constitutes a theoretical framework for dealing with the second aim of this thesis, which is finding out what is critical for teacher educators to facilitate experiences that enable student teachers to learn science, teach science, and integrate theories of science didactics with practice in the unfamiliar, resource-rich, and multi-sensory environment. Hence, it is about finding out how student teachers handle situations and what they need to understand in order to be able to do in their practice. This implies that teacher educators must become aware of the different ways they themselves might handle these situations in order to enable student teachers to handle them in powerful ways (Marton, 2015).

On another level, variation theory is used as an analytical tool in the first study of this thesis to identify student teachers' opportunities for learning science when they discuss science in small groups, without a teacher educator present (see Paper 1). In addition to the use of variation theory in the first study, a framework of small-group discussions (Bungum et al., 2018) is applied. This framework is briefly described in sub section 3.1.4 after the outline of variation theory.

In the first study, variation theory lends its principles of how to analyze student teachers' opportunities to arrive at a shared understanding of particular science content by the means of the small group. The areas of analysis with variation theory are illustrated by the tetrahedron in two ways. In the first case, it encompasses the entire tetrahedron and its internal relationships. While in the second case, the area of analysis is illustrated by the relationship between the student teachers and the science content (see Figure 1).

In the section that follows, Section 3.2, an outline of the theoretical frameworks used in the second study (see Paper 2) are presented. In this study, the theory of affordances (Gibson, 1986), narrative-making in teaching (Bruner, 1991) and MER in biology education (Tsui & Treagust, 2013) are used as theoretical points of departure. The main areas of analysis are illustrated by the tetrahedron's surfaces, student teachers - artifacts - science content – as well as the relationship between the student teachers - science content - students – artifacts. That is, the whole tetrahedron (see Figure 1). This section concludes with an argumentation about why the theory of affordances are used in the second study.

Finally, the theoretical frameworks used in the third and fourth studies are described in Section 3.3. The area of analysis in both studies encompass all the relations and surfaces of the tetrahedron and the studies are based on the same set of empirical material, generated with so-called video-stimulated reflection (VSR). The difference, however, is the focus of analysis and theoretical frameworks. In the third study (see Paper 3), the focus is on exploring an approach to VSR and to identify to what extent it can facilitate student teachers' reflective process. To detect a reflective process, the notion of framing and reframing (Schön, 1983) and the reflective cycle (Lee & Loughran, 2000; Mackinnon, 1987) are used. In contrast to the third study, the fourth study's analytic focus is on the content of reflection and not on reflection as such. The focus of interest comprises the challenges student teachers face in teaching science at the science center. In this study, the didactic tetrahedron is used as an analytical tool to identify the student teachers' orchestration of the interplay between science content, artifacts of the exhibition, and students (Rezat & Sträßer, 2012). That is, to identify student teachers' creating of didactical situations.

3.1 Variation theory of learning and teaching

According to variation theory, knowledge is not something out there to take in, but something that is constituted in the relationship between the individual and the world (Marton & Booth, 1997). According to Marton (2015), there is a non-dualistic relationship between the learner and what is to be learned (the object of learning) in a learning situation. From a variation theory perspective, learning is always

> directed at 'something' (a phenomenon, an object, or certain aspects of the reality) and is related to how people make sense of it, thus developing a certain skill, value, or capability in dealing with it – this is referred to as an 'object of learning (Ling et al., 2006, p. 2).

Unlike a specific topic or general goals for teaching, the object of learning is delimited, detailed, and selected in relation to a particular group of students (Marton, 2015). Hence, the teacher's role is not to deliver knowledge but to make the learning of an object (e.g., phenomena, concept, and situation) possible by providing the necessary conditions for such learning. The first key principle of teaching to enable learning is *relevance structure* and the second is the *structure of variation* (Marton & Booth, 1997). "If the relevance structure of a learning situation is the driving force of learning, its chief mechanism is variation" (p. 145).

3.1.1 Building relevance structure for the learners

The major issue in teacher education is how to prepare student teachers for the unknown, utilizing contemporary theories of science and science teaching. According to Marton (2015), variation theory is an attempt to address this uncertainty. In relation to subject-matter didactics, variation theory focuses on what is to be learned and how learning of this 'what' can be made possible (Kullberg, 2010). The theory suggests that when learners encounter new and unknown situations, they will deal with these according to how they perceive them (Marton, 2015). In the situation, some things come to the fore of the learner's attention, and other things remain in the background. What is in the foreground of attention for one learner may be very different from what is in the foreground of others (Marton & Booth, 1997). Depending on previous experiences, learners pay attention to different aspects of the situation, but particularly those that they consider are more relevant to them (Runesson, 2006). In the words of Lo (2012),

> the way that a student responds to a learning situation depends on how he or she sees the situation, or the relevance structure of the learning situation, teachers should pay attention to building a relevance structure between the students and the object of learning. (p. 23)

If teachers are to build relevance for the students, they need to make sure that the learners understand what the teaching is aimed at, what it requires, and what it will lead to (Marton & Booth, 1997, p. 180). Accordingly, learners' ways of responding and acting in a given situation depend on how they understand and find the object of learning (Marton et al., 2004). A natural way to build a structure of relevance for the learners is to take a departure from the learners' concerns, questions, and actions, since they impose a relevance structure on the situation that could be used by the teacher to structure for learning (Marton & Booth, 1997). In this thesis, the notion of *relevance structure* provides a useful concept to describe what student teachers are struggling to build for their students and implicitly become aware of when reflecting upon their science lessons. Building relevance structure is equally important for teacher educators in their work of scaffolding student teachers' learning.

3.1.2 The structure of variation

The second principle of variation theory is *structure of variation* (Marton & Booth, 1997). In order to facilitate learners to develop powerful ways of acting or handling situations in the moment, or in the future, teachers must arrange opportunities for their learners to develop powerful ways of understanding the same (Lo, 2012). The ability to handle situations in a powerful way depends on what aspects are discerned in the situation. Thus, teaching should empower learners to extract those aspects in a situation that are critical for understanding and handling that particular situation in a powerful way (Marton & Booth, 1997). In the words of Marton (2015): "Without learning to see, you cannot learn to do", and teachers must find out "what the students need to learn to see in order to become able to do certain things, under certain circumstances" (pp. 255-256). The implication is that teachers need to find out the critical aspects the students need to see or understand and be able to apply them in designing teaching. It is therefore of great importance, whether you are a teacher educator or a student teacher, to see the learning situation from the learners' perspective and how they interact with the objects of learning in any given situation.

In order to discern critical aspects of an object of learning, variation is needed (Maunula, 2018). For every discerned aspect of an object of learning, there is a corresponding dimension of variation that is opened up (Marton & Booth, 1997). What aspects are critical is relative to the learner and to what is to be learned – the object of learning (Marton, 2015). What is critical for one learner may not be critical for others. To discern a critical aspect, is to open a dimension of variation that has not yet been opened to the learner. It involves making differentiations between the opened dimension and other dimensions - as well as between different values within the dimension. Then all those discerned aspects (dimensions of variation) should be brought in one awareness simultaneously (Marton, 2015). The differentiations can be described as patterns of variation and invariance (Ko & Marton, 2004). The basic pattern is *contrast* and it refers to making distinctions between specific dimension of variation and within. For example in order to discern a particular root structure of a tree (which has not yet been discerned by the learner) it has to vary against a background of sameness (Marton et al., 2004). Otherwise, the feature would not be discerned. Contrast can also be described as discerning what something is and what it is not (Pang & Ki, 2016). The second pattern is *separation* and is closely linked to the third pattern *generalization* (Marton, 2015). For the learner to discern the particular root structure, she or he must understand the concept of roots, separating the particular structure (e.g., taproot) from what it is a structure of – the structure of a taproot. When the learner has made this separation, the learner can *generalize* and understand that many different trees can have the same particular root structure. Thus, the structure of the root becomes invariant. The last pattern is *simultaneity* or *fusion* and indicates that the learner discerns two or more aspects bringing them all to her or his awareness simultaneously (Xu, 2019). In this way, the learner are given the opportunity to understand the object of learning in a more powerful way than before (Marton, 2015).

3.1.3 How learners can generate patterns of variation and invariance together

Commonly, when investigating learning in teaching situations, the empirical material is generated from classrooms where the teacher is the leading agent for providing opportunities for the students to experience critical aspects and make the object of learning their own (Runesson & Kullberg, 2017). The potential of such research is that it enables teachers to design teaching in a way that allow the learners to discern the critical aspects (opening dimensions of variation and invariance) of an object of learning and broadening their ways of understanding it, seeing it in a more different and powerful way (Bowden & Marton, 1999). In addition, variation can be generated by the learners, or by the environment. Regardless of who generates the variation, a shared understanding of the object of learning can only be achieved if the learners "share some common ground on which further interaction can be based" (Marton et al., 2004, p. 185). In the first study of this thesis (see Paper 1), this particular phenomenon is examined. By studying how, and to what extent, student teachers generate patterns of variation and invariance; it is possible to identify their shared understanding of particular objects of learning in of small group discussions (Booth & Hultén, 2003). Although the student teachers participating in the research do not consciously and systematically use patterns of variation and invariance in their group discussions during their lesson planning, such patterns are still created. According to Marton (2015), both teachers and students use variation and invariance patterns more or less unconsciously and thus, making learning possible.

3.1.4 Small-group discussions – a complementary framework to variation theory

As indicated in the results of the study by Booth and Hultén (2003), students adopt a certain inquiry approach to the object of learning in order to reach a shared understanding (questioning, contributing with ideas, disagreeing, and comparing), and in that way create patterns of variation and invariance. By adding a complementary framework of small-group discussions (Bungum et al., 2018), initially introduced by Mercer (2004), another tool is available for identifying and communicating student teachers' opportunities to reach a shared understanding of objects of learning in the groups. If the theory of variation is closely linked to what is to be learned and how learning is made possible of particular objects, in group discussion, then small-group discussions is a framework that describes the character and quality of these talks. The framework is based on three archetypal forms of talk, including disputational, cumulative, and exploratory talk (see Table 1). These forms of talk differ in terms of how the object of learning is approached and the possibility of reaching a solution - a new understanding. The advantage of the framework is that the forms of talk correspond to different degrees of the presence and density of patterns of variation and invariance. Furthermore, it helps observers, for example, teacher educators, to understand the character of the student teachers' talk through the way they make use of language to make inquiries into objects of learning.

Table 1. The table is adapted from Table 1 in Paper 1 and, illustrates the framework of small-group discussions as elaborated by Bungum et al. (2018) from the initial framework of Mercer (2004).

<table>
<tr><td>Disputional talk</td><td>Disputational talk is characterized by disagreement and individualized decision-making.</td><td>Bungum et al. (2018) have divided disputational talk into two forms: Independent statements– signifying merely that student teachers are not building on each other's utterances.
Confirmatory talk – involves students simply repeating or confirming what is said by their peers.</td></tr>
<tr><td>Cumulative talk</td><td colspan="2">In cumulative talks, the participants build on each other's utterances and construct a joint body of knowledge accumulated by individual contributions.</td></tr>
<tr><td>Explorative talk</td><td colspan="2">In explorative talks, the participants engage critically with each other's ideas. Statements and suggestions are offered for joint consideration; these may be challenged to reach a decision or agreement on a shared understanding.</td></tr>
</table>

3.2 The theory of affordances and complementary frameworks

In the second study of this thesis, the theory of affordances (Gibson, 1986) constitutes the main framework. As complementary theoretical frameworks, Bruner's notion of narrative-making (Bruner, 1991), and Tsui and Treagust's (2013) model of MER in biology education are used. This section presents a description of how these theoretical frameworks contribute to addressing the research questions in the second study (Paper 2).

The term affordances was initially introduced by Gibson (1986) and originates from his ecological perception theory (Achiam et al., 2014). The theory became popular through Norman's (1988) work in design and human-computer interactions, and is today used in various research fields (Hammond, 2010). As in variation theory, the theory of affordances rests upon the idea that there is a logical relationship between acting upon something and perceiving. Marton and Booth (1997) express it in this way: "the capability for acting in a certain way reflects a capability of experiencing something in a certain way…You cannot act other than in relation to the world as you experience it." (p. 111). This suggests that when we perceive something, for example, a surface, an object, or a situation, our actions are based on how we perceive those (Gibson, 1986). As in variation theory, affordances rest upon the idea that a learner will first perceive the whole (e.g., the whole tree) before discerning its aspects (root structure), its dimensions of variation (taproot), before bringing them together as a more broadened understanding of the whole again (Gibson & Gibson, 1955; Marton, 2015).

However, according to (Marton, 2015), there is a difference between variation theory and Gibson's idea of how people perceive situations, objects, and things in the world. According to Gibson (1986), the theory of affordances rest upon the idea that people (and animals) "pick-up" or act upon the affordances of an environment or object directly, for example, acting upon a ball's affordances of kicking or throwing (May, 2010). While the variation theory point of view suggests that people pick up or act upon affordances in the world, not only directly but also through their past experiences. That is, by using what they already know (Marton, 2015). Rietveld and Kiverstein (2014) suggest that acting upon affordances also depends on people's abilities to do so and the norms that are embedded in the context. This thesis holds the view from variation theory that people use their past experiences and memories when perceiving and acting upon affordances in the world.

In an outline of the theory by Chemero (2003), an affordance is described as

> a resource that the environment offers any animal that has the capabilities to perceive and use it. As such, affordances are meaningful to animals: They provide opportunity for particular kinds of behavior. Thus, affordances are properties of the environment but taken relative to an animal. (p. 182)

Accordingly, affordances should be seen as relationships between the perceiver's abilities and the aspects of a situation or environment. However, affordances are objectively present as action opportunities, independent of the relationship between the individuals who perceive and their environment (Chemero, 2003). This means that even though an individual cannot perceive an action opportunity, the opportunity can still exist. At the same time as affordances of, e.g., a situation, an object, or a surface, offers opportunities to certain kinds of actions, it may constrain other actions (Greeno, 1994). Furthermore, affordances are not limited to what can be perceived visually, but also to what can be "felt and heard" (Hammond, 2010, p. 208). As space, time, or a situation change, the affordances of those dimensions change (Achiam et al., 2014). For teachers to achieve results in their interaction with students, they need to perceive different action opportunities and constraints (affordances) relevant for their students' learning in a given situation (Wagman et al., 2018). However, to engage in an affordance in a specific situation, the teacher (and students) needs to have the ability to do so and discern its pedagogical affordances (Ihanainen, 2019). Perceiving and engaging in affordances can be learned but requires training (Rietveld & Kiverstein, 2014). Thus, the theory of affordances contribute not only with an understanding of affordances as opportunities and constraints on actions upon the environment in terms of e.g., reaching, grasping, sitting, walking, but employ also an ability in a specific context (Rietveld & Kiverstein, 2014). In contrast to variation theory, which is focused on the process of learning and teaching something specific, the theory of affordances provides a framework of how objects, environments, etc. may suggest certain actions relative to the person who perceives.

In the second study (see Paper 2), the notion of affordances outlined above is used to examine student teachers' actions upon the affordances of the living rainforest exhibition when teaching the curriculum topic 'ecosystems'. Furthermore, it is investigated whether the exhibition appears to afford the actions student teachers want to do. The theory of affordances contributes with a framework for examining the area of the tetrahedron that concerns the relationship between the student teachers, the physical environment, and the science content (see Figure 1). In addition, that area's relationship to the students is discussed. By examining student teachers' actions upon the exhibition in relation to particular science content, it is possible to gain insight into how they perceive these affordances (Gibson, 1986; Marton, 2015). Thus, teacher educators can benefit from gaining a deeper understanding of what opportunities and constraints student teachers perceive in these material-rich environments and use them as representations to be able to provide the right support and tools in their learning to teach (Kozma et al., 2000; Nyberg et al., 2019).

3.2.1 Narrative-making in teaching

As a complementary framework to the theory of affordances, Bruner's (1991) notion of narrative-making is used in the second study. According to Bruner (1991), humans organize experiences in and through narratives. Thus, narratives are essential representations of human knowledge (Doyle & Carter, 2003). Teachers – as well as student teachers' curriculum realities, can be understood as narratives because teachers translate their knowledge into telling stories (Gudmundsdottir, 1991). Researchers suggest that narrative as a structure for organizing our knowledge can be used as a way to teach science (Avraamidou & Osborne, 2009; Prins et al., 2017). However, teachers' narrative-making, regardless of experience, are colored by their ideas, beliefs, knowledge, and experiences from their own schooling. To enable the narrative as a structure to organize science knowledge, Bruner (2003) suggests that teachers and their students need to view science-making as a generator of knowledge and representations, created from a particular perspective. By viewing the scientific process in this way, science teaching and learning in the classroom can be approached as a co-construction of science ideas and principles – a co-construction of curriculum narratives (van den Akker, 2003). According to Stein et al. (2007), it is about how teachers bring "the planned curriculum to life and, in the process, create something different than what could exist on the pages of the book or in the teacher's mind or lesson plan" (p. 321). The extent to which teachers can adopt this approach depends on their views on science and science teaching. As mentioned in the background chapter, many student teachers carry perceptions of science as a finished product 'out-there' to be learned, and see science teaching as 'telling'. These views are often connected to the ways they approach the formal curriculum (Shawer, 2010). For, example, interpreting the curriculum as an 'order of content to be delivered' can be viewed as a type of curriculum narrative (Doyle & Carter, 2003). By using Bruner's notion of narrative-making makes it possible to identify different types of narratives that emerge as the student teachers, construct their curriculum about ecosystems. Furthermore, how these narratives can be related to their actions upon specific affordances of the living rainforest exhibit.

3.2.2 Multiple external representations (MER) in biology education

In addition to the theories of affordances and narrative-making, the model of MER in biology education, introduced by Tsui and Treagust (2013) is used in the second study. In science education, teachers and textbooks use representations to support their narrative in the teaching to enable their students to understand phenomena that are not visible to the naked eye (e.g., atoms, molecules, cells etc.). Johnstone (1993) introduced the concept of MER in chemistry and suggested that the use and understanding of macro, sub-micro, and symbolic levels of representations, and the translation between them, support the understanding of key scientific ideas and principles. However, there is a difference between representations in chemistry and biology education. In chemistry, each level is a representation of the same phenomenon, while "biological knowledge, unlike chemical knowledge, extends to multiple, hierarchically organized levels of nested but different biological entities" (Tsui & Treagust, 2013, p. 8). In the context of student teachers' teaching about the curriculum topic ecosystems in the living rainforest, this is certainly the case. To address this issue, Tsui and Treagust (2013) introduced the three dimensional model of MER in biology education. The first dimension is *modes* of representations, the second is *levels* of representations, and the third is the *domain* knowledge of biology. In the model, modes of representation are viewed "as a continuum of increasing abstraction, of which human language is deemed the most abstract mode of representation"

(Tsui & Treagust, 2013, p. 7). It begins by externally representing biological ideas and principles with concrete real-world objects and actions, including gestures, further on to photos and animations, realistic drawings, figures, graphs, equations, and finally, to the most abstract mode, in which inputs are made by linguistic means. In addition to the *modes* of representation, there is the second dimension with *levels* ranging from macro (green plant) to sub-micro (molecules). Finally, the third dimension of the model involves *domains* of knowledge in living systems. The domain is not exclusively about biology; it includes chemistry, physics, and mathematics. Furthermore, biology can be divided in sub-domains like ecology, evolution, etc. For learners to achieve an adequate understanding of biological phenomena, Tsui and Treagust (2013) argue that they need to think carefully about all three dimensions of representations. To do that, teachers need to know a range of representational tools in teaching science to help students translate between different levels and different domains of representations by using different modes (Johnstone, 1993; Schneider & Plasman, 2011). Hence, the model of MER offers a useful model to describe the student teachers' ways of handling the exhibition's objects in terms of representations in their construction of narratives about ecosystems. In summary, the theory of affordances, narrative-making and the three dimensional model of MER offer useful local frameworks for in-depth analyses of how student teachers' act upon the affordances of a material-rich and multi-sensory living exhibition when teaching about ecosystems.

3.3 Theory of reflection and reflective cycle

In the third study (see Paper 3), the focus of analysis is on exploring an approach to video-stimulated reflection (VSR) and to identify to what extent it can facilitate student teachers' reflections on their teaching at the science center. Thus, in this study, the student teachers reflections on teaching touch upon the different surfaces of the tetrahedron as well as the whole tetrahedron. In order to detect the reflective process in the VSRs with the three groups of student teachers, the notion of framing and reframing (Schön, 1983) and the reflective cycle (Lee & Loughran, 2000; Mackinnon, 1987) are used. In the following subsections, these theoretical frameworks are described.

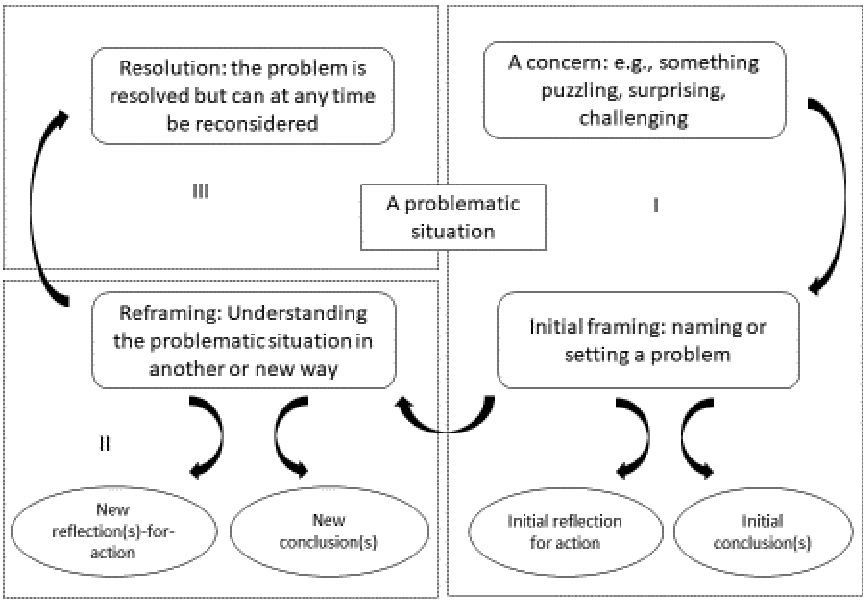
3.3.1 Reflection as a process of framing and reframing

The motivation of a teacher to pay attention to a teaching situation is often driven by emotions and values and can be understood as a concern (Lee & Loughran, 2000). A concern may arise in the conflicts between what one intends to accomplish, what one thinks one is accomplishing, and what is actually happening (Danielowich, 2007). Thus, the reflective process becomes an act of recognizing conflicts, or problematic situations and making reconsiderations of the questions: how should this content be made accessible for the students? Moreover, why should certain content be taught in a certain way? For reflection to be initiated when sharing and listening to each other's teaching concerns, teachers need the ability to view a problematic situation in new ways. According to Schön (1983), reflection requires framing – to identify a problem, and reframing – to view the problem from another perspective. The process of reframing also offers opportunities to see new possibilities for future actions in teaching (Beauchamp, 2015; Dillon, 2011; Lee & Loughran, 2000). However, facilitating reflective practice is, as Russell (2005) argues, not about instructing people to reflect. Furthermore, the facilitator alone cannot discern a problematic situation in teaching since this may exclude the student teachers' experiences of the situation. Therefore, the facilitator (e.g. researcher and/or teacher educator) needs to use her or his own reflections in action together with thoughtfulness, explicitness, and endurance. Therefore, in the third study, it is important in the role of facilitator to strive for these qualities to enable student teachers to engage in reflective process in the VSR interviews.

3.3.2 Reflective cycle model - an analytical tool for detecting reflection

In the third study, the focus is on the student teachers' reflective process, addressing the question of how and to what extent an approach to VSR could facilitate student teachers' collective efforts to imagine how they would improve their practice. The VSR interview, which is described in detail in Chapter 4, Methods, fulfills two functions. On the one hand, to detect and analyze a reflective process. On the other hand, to offer an opportunity for student teachers to create a reflective space for collective experiences.

Figure 3. The figure is adapted from Figure 1 in Paper 3, and illustrates the adapted reflective cycle model, inspired by Lee and Loughran (2000), and initially developed by Mackinnon (1987). The model is subdivided into the three phases, I–III of the reflective cycle.



To identify acts of reflection in the VSR interviews with the three groups of student teachers, a modified version of Mackinnon's 'clue structure' (Mackinnon, 1987, p. 140) was used as an analytical framework. According to Mackinnon (1987), the 'clue structure' helps to identify and separate student teachers' acts of reflection from rationalization. This meant separating reflection from actions that "justify, or defend, a particular teaching behavior" (Mackinnon, 1987, p. 139). The first clue in Mackinnon's clue structure, seeks to identify the phases of the reflective cycle. That is, to detect acts of framing and reframing in the student teachers' discussions. The second clue identifies shifts of perspectives from which the student teachers' view situations in their teaching, for example, shifting from a teacher-centered to a student-centered perspective. The third clue, seeks to detect if acts of reframing lead to new conclusions about the situation or new reflections for future actions (implications). Finally, the fourth clue looks for evidence of shifts from viewing their teaching from their own experiences as school students to make sense of their students' point of view (Mackinnon, 1987). In this study, the fourth clue has been merged with the second clue. The three clues are used as guidance in detecting reflection and linked to of the reflective cycle.

In the modified model of the reflective cycle (see Figure 3), a reflective cycle begins with the student teachers sharing of a concern. A concern can be identified in connection to pausing of the video viewing or in the discussion, taking place within the same pause. The concern may then be initially framed, which means that the problematic situation is tentatively identified and described (Box I). In this phase, the student teachers may draw initial conclusions and make reflections for future practice. The clue structure helps to distinguish between actual conclusions and justifications. That is, to distinguish between acts of reflection and 'defending' a particular behavior in teaching. In the next phase, reframing (Box II), the problematic situation is reconsidered, seeing it from another perspective. In this phase, the student teachers may articulate new conclusions and make new reflections for future practice actions. For the reflective process to move into resolution (Box III), the student teachers need to reconsider the problematic situation and find a solution. To find a solution requires the opportunity actually to test the solution in practice and experience the outcome. However, the student teachers can imagine a possible solution to the problem and possible changes to future actions. In this study, the word implication is changed to the synonym, 'reflections for possible future actions'. The reason is to highlight that this is a dimension of reflection, which is an essential ability in teacher practice (Beauchamp, 2015; Dillon, 2011).

4 METHODS

This chapter begins with a presentation of the educational context on which this thesis reports, followed by an outline of the methods used to collect the three sets of empirical material, and how these data sets are analyzed, in each of the four studies.

4.1 The educational context

The educational context encompasses a course module developed by teacher educators at University of Gothenburg in collaboration with Universeum science center pedagogues. The module's overall aim is to enable student teachers to explore the potential of an out-of-school science environment, in this case, a science center, for teaching and learning science. It focuses on science instruction practice involving planning and implementing science lessons in the science center exhibitions with groups of school students. The module includes becoming familiar with the exhibitions – as well as planning and implementing short science lessons with invited students from schools. It also incorporates evaluating and reflecting upon practice. The course module has, since beginning in 2014, become a permanent feature in two teacher programs, one of which is a four-year-long program of training student teachers studying science for primary school teaching (students age 6-9 or 10-12). The other program is a one-year teacher training for secondary school teaching (students age 13-19). In the four-year-long program, the course module is included in a science and technology course focused on facilitating learning in science and science didactics. In the short teacher program, the course module constitutes a one-week internship at the science center for the whole class of student teachers.

To support student teachers' ability to plan, discuss, implement, and evaluate teaching, a common process within teacher education is to organize teaching and learning situations in small groups. Accordingly, the student teachers are divided into smaller groups of 4-5 in each group. They work in these small groups throughout the course module's different phases (planning, implementing, and evaluating/reflecting upon teaching), except for the individual written reflections, which they hand in after completion of the practice at the science center. In connection with the introduction to the course module assignment, the student teachers are asked to consider the questions: why might teachers use an environment such as a science center for learning science and technology? What opportunities and challenges do they see? What do they take as their starting point when planning their science lesson? Is it the exhibition environment, the formal curriculum's central content and knowledge requirements (Skolverket, 2011), the students, the student teacher's own interests, the course literature, or other factors? The aim of these didactical questions is to help the student teachers in their lesson planning.

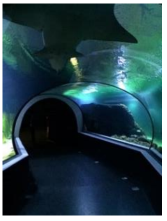
The primary and secondary student teachers performed the same course module assignment at the science center. The structure of the course module is described as follows:

- Student teachers are introduced to the science center setting and assigned an exhibit and a theme to plan and prepare a 30-minute lesson in science.
- Preparations are carried out in groups of 4-5 students in each age level (6-9, 10-12, and 13-19).
- The groups submit their planning (in writing or orally) to the course teachers and the science center educators before implementing their lesson.
- The science center educators support and advise the student groups in their work.
- The lesson's implementation is done with groups of students (about 15 in each) at the ages of 6-9, 10-12, or 13-15. The school classes are invited to the science center for this occasion.
- The 30 minute-lessons are carried out twice after each other. The student teachers have the opportunity to reflect in the group with one of the university teachers or the science center pedagogues between the two lessons, and after they are completed.
- After the small group reflections, all student teachers gather for a whole group reflection together with the university teachers and science center educators.
- Each student teacher submits an individual written reflection (this was true only for the primary school student teachers) to the university teachers after completing the lesson.

4.2 An overview of the student teachers participating in the research

The following Table (Table 2) presents an overview of the participating student teachers, including the cohort of student teachers they belong to, the teacher education program, year in teacher education, their assigned science theme/topic, and the designated exhibition. Although there are differences between the student teachers as to teacher education program, gender distribution, educational background in science, and interest in natural science, they are all new to planning and implementing science lessons in the material-rich and multi-sensory settings of the science center.

Table 2. The table is adapted from Table 2, in Paper 1, and shows an overview of the participating student teachers, assigned exhibitions, and themes.

Groups of student teachers	Assigned exhibition	Theme/topic	Exhibition
'Life in space group' Five student teachers, preparing for lower primary school (students age 6-9). Compulsory science and technology course (15 ECTS), during year 2 of 4	Space exhibition	Life on the ISS[1]	
'Ecosystems group' Five student teachers, preparing for upper primary school (students age 10-12). This was an elective science and technology course (30 ECTS) during year 2 of 4.	Living rainforest exhibition	Ecosystems	
'Evolution group' Four student teachers, secondary school (students age 13-19). Science didactic course (1ECTS), halfway through one-year-long supplementary prepatory training (the student teachers have at least a bachelor degree in engineering or science).	The exhibition with aquariums and terrariums	Evolution	

[1] International Space Station

4.3 The three exhibitions at the Universeum science center

The following sections briefly describe the three science center exhibitions that the student teachers were assigned in the course module assignment.

4.3.1 The space exhibition

When collecting the empirical material for this thesis, the space exhibition's salient feature was Christer Fugelsang, the first Swedish astronaut traveling with a team to the international space shuttle (ISS). At the time of collecting the empirical material, the space exhibition consisted of 1:1 size models, imitating parts of the ISS's interior—for example, a model of a space toilet, sleeping equipment, and exercise equipment. In addition to these models, there were different TV screens, showing videos of astronauts' working and exercising in space.

4.3.2 The aquarium hall

Water is one of the main elements featured in the living exhibitions and is intended as a connecting link between, on the one hand, the exhibition 'Water's way,' a model of Swedish nature and watercourses from north to south, and on the other, the aquariums with cold and warm water marine animals. The marine animals that can be observed are typical in the sea on the Swedish west coast and the tropical and subtropical seas. In addition to the aquariums, there is a terrarium with gecko lizards placed in the aquarium hall. The theme 'water' continues from the aquarium hall to the living rainforest exhibition.

4.3.3 The living rainforest exhibition

The living rainforest exhibition is a South Central American tropical rainforest model. According to the science center, the overall aim of the exhibition is to highlight biodiversity. The idea they want to communicate is that the living rainforest affords visitors opportunities to study some of the many adaptations and interactions among rainforest organisms. The temperature in the exhibition is 20-25 °C, but it is perceived as higher because the relative humidity is often over 90 %. Although the exhibition aims to highlight adaptations and interactions among plants and animals, the sound from waterfalls and animals dominate, attracting visitors' attention (e.g., monkeys, aquatic animals, birds, and butterflies).

4.4 Methods for collecting the empirical material

This thesis is based on three sets of empirical material. The first set consists of video footage of three groups of student teachers' lesson *planning* meetings. The second set of data consists of video footage of the 'ecosystems group's *implementation* of their two identical science lessons about ecosystems. Finally, the third set of empirical material encompasses the student teachers' *reflections* upon teaching science at the science center. This data set consists of VSR interviews with each of the three groups of student teachers. In the overview (see Table 3), the four studies and corresponding research questions, the methods for collecting the empirical material, and the time of collection of the material are presented. In the next section, there follows a more detailed description of the methods for collecting the three sets of empirical material.

Table 3. The table shows an overview of the four studies and corresponding research questions, empirical material, and time of the collection of the empirical material.

Three sets of empirical material	Studies and research questions	Empirical material	Time of collecting empirical material
Planning	Study 1: Q 1: How and to what extent are opportunities for learning science constituted through student teachers' talk in small-group discussions?	Video footage of each group's planning meetings (1-3 meetings), in a total of 2 hours per group. These took place in a training room at the science center.	Video footage of the secondary student teachers was carried out in May 2016. The video footage of the primary student teachers was carried out in September 2016.
Implementing	Study 2: Q2: What affordances of the presented living rainforest do the student teachers act upon in enacting the curriculum topic 'ecosystems'? Q3: In what ways do the "presented" rainforest appear to afford such teaching actions?	Video footage of the 'Ecosystems' group when implementing their two identical 30-minutes science lessons in the living rainforest exhibition. Documents: written lesson-planning and lesson script.	September 2016
Reflecting	Study 3: (Q4) How and to what extent can an approach to video-stimulated reflection interviews facilitate student teachers to create a space for collective experiences to imagine how they would improve their practice? Study 4: (Q5) What are the challenges student teachers experience when teaching science at the science center? (Q6) What aspects of science didactics in these challenges becomes central in creating didactical situations?	Video-stimulated reflection interviews with each of the three groups. A total of 2-2,5 hours interview with each group. The student teachers' viewed their teaching to school students (2*30 minutes lessons). The interviews were audio-recorded. The same empirical material was used in the fourth study; however, with another purpose and focus.	December 2016

4.4.1 Student teachers' *planning* meetings

The video footage in the first study (Paper 1), took place in a training room at the science center. The researcher set up the video camera at the beginning of the planning meeting but did not stay in the room during the meeting. Instead, the student teachers managed the camera. For example, student teachers would stop the video when taking a break or leave the room to revisit the exhibition. The video footage allowed for careful observation and documentation of situated expressed experiences within the educational context (Derry et al., 2010). Furthermore, the video footage captured discussions within the groups and offered opportunities for the researchers to revisit sequences and (critical) events for repeated examinations. They also enabled making more direct links between observations and interpretations (Powell et al., 2003).

4.4.2 Student teachers' *implementation* of lessons

Video footage was also used as a primary method for collecting the second set of empirical material. In this work, the focus of research interest was on the 'ecosystems group' and the group's implementation of their planned lesson about the curriculum topic ecosystems in the living rainforest exhibition. Here, the word 'curriculum', indicates that the science topic is conveyed in the formal curriculum. In line with this focus, the second study, (Paper 2) examined the ways the student teachers' act upon the living rainforest exhibition when teaching about ecosystems to students in upper primary school. In collecting the empirical material, video footage of the student teachers' two 30-minute lessons were made. The use of video footage allowed for capturing the student teachers' actions and interactions with the school students and the exhibition environment. As in the first study, video footage allowed for revisiting (critical) events for repeated examinations (Powell et al., 2003). This was important since the focus was on how the student teachers acted upon the exhibition environment's affordances, as they perceived it, and used them as representations in teaching. It also allowed for examining how the exhibition environment appears to afford the student teachers' didactical actions. In addition to these advantages, the video footage constituted a central part of the third set of empirical material, the reflection phase.

4.4.3 Student teachers' *reflections* on teaching (VSR)

The method used to collect the empirical material for the third and fourth study encompassed an approach to VSR interviews with each of the three groups of student teachers. As a part of the course module, the groups had the opportunity to reflect and evaluate their teaching between the two lessons and afterwards. Although these opportunities were engaging activities for the student teachers and from a teacher educator perspective, they were, due to their nature, challenging to study in terms of facilitating and detecting reflective practice. This collective reflective practice allowed student teachers to 'step outside' their practice, view their own, and fellow student teachers' teaching from a distance, and share concerns with each other. A concern can be viewed as a conflict between one's intentions what do you think you are doing and what you actually do in your teaching. Reflection thus becomes an act of recognizing conflicts and reconsidering the 'how' and the 'whys' in teaching (Danielowich, 2007). In light of the complexity of the teaching and reflecting situation, the empirical material was collected by interviews through VSRs (see Table 4) two months after completing the course module at the science center. This choice was primarily of a pragmatic nature related to student teachers and the researcher's availability. However, the time period also allowed the student teachers not only to step outside their practice, and view it from a distance, but also to think about it in light of their progression in teacher training.

The purpose with the VSRs was not primarily to have the student teachers recall what they were thinking at the time of teaching at the science center but to facilitate a reflective process in which they could recognize, share and reflect upon problematic situations in their teaching together. To allow for the student teachers autonomy in their reflective process, they were given control over the video viewing of their science lessons and could at any time stop the video and share their concerns. A semi-structured interview protocol was employed as background support (Lee & Loughran, 2000). The interviews were audio-recorded, a total of about two hours per group. The interviews took place at the university and the student teachers viewed the video of their first, and second lessons, with a reflective discussion in between, and after.

Table 4. The table is adapted from the Table 1 in Paper 3, and presents the structure of the VSR interviews.

	VSR interview	Description
1	VSR on the first lesson, including the subsequent discussion (60-75 minutes)	The student teachers could pause the video footage at any time to share their teaching concerns. In the subsequent discussion about lesson 1, the student teachers were asked to share their concerns about the first lesson.
2	VSR on the second lesson, including the subsequent discussion (60 - 70 minutes)	The student teachers could pause the video footage at any time to share their teaching concerns. In the subsequent discussion, the student teachers were asked to share their thoughts and feelings about the second lesson in relation to the first.

4.5 Analysis in each of the four studies

In the following section, the analytical frameworks used in the analysis of the empirical material in each study are presented. However, they are only described briefly and more detailed descriptions of these theoretical frameworks can be found in Chapter 3 and in the respective papers.

4.5.1 Study 1 - Analysis of all three group's *planning* meetings

To answer the research question, how and to what extent are opportunities for learning science constituted through student teachers' talk in small-group discussions (Q1), variation theory was used as an analytical framework. By drawing upon variation theory in the analysis, it was possible to explicitly focus on aspects that the student teachers discern concerning the object of learning and to describe these as dimensions of variation. The focus was on detecting when a new dimension of variation was opened, on the one hand, and then on how it was acted upon (e.g., by using the patterns contrast, generalization, separation, and simultaneity). According to variation theory, the presence of relevant patterns of variation indicates an opportunity for the student teachers to see an object of learning in a new way (Marton, 2015; Xu, 2019). To understand better the quality and nature of the student teachers' small-group discussions when opening the dimensions of variation, the final step of the analysis applied the framework of small-group discussions suggested by (Bungum et al., 2018). This meant that in parallel to the variation theory analysis, all of the identified content-focused units were described as independent statements, confirmatory talk, cumulative talk, or exploratory talk (e.g. as discussed in Chapter 3, Table 1).

4.5.2 Study 2 - Analysis of the 'Ecosystems group's' *implementation* of lesson

The second study set out to investigate what affordances of the living rainforest the student teachers act upon in constructing the curriculum topic 'ecosystems'. (Q2) Furthermore, we investigate in what ways do the rainforest appear to afford such teaching actions? (Q3) To answer these research questions, the theory of affordances (Gibson, 1986), Bruner's (1991) notion of narrative-making, and the model of MER (Tsui & Treagust, 2013) were used as theoretical points of departure (see Chapter 3). Through a thematic analysis (Braund & Reiss, 2006), patterns in the student teachers' actions upon the living rainforest in teaching about ecosystems were examined. In connection to this analysis, the student teachers' ways of using MER in relation to their actions upon the living rainforest were analyzed, and whether these actions were objectively available as opportunities by the presented rainforest, or not. In the latter case, the interest was on finding patterns in how the student teachers handled the living rainforest's constraints to actions. In the analysis, it became apparent that the student teachers' use of MER combined with their actions upon the presented rainforest differed within the group. To describe the differences between types of constructed narratives emerging in the student teachers' science lessons, Bruner's (1991) notion of narrative-making related to the different curriculum approaches (see e.g., Shawer, 2010; Stein et al., 2007; Wallace & Priestley, 2017) was used. Thus, in this way, it was possible to discuss these emerging narratives in relation to their pedagogical affordances.

4.5.3 Study 3 - Analysis of all three groups' *reflections* on teaching using VSR

The third study set out to answer the research question, how can video-stimulated reflection interviews with student teachers be designed in order to facilitate a reflective process? (Q4) The study aimed at examining an approach to VSR in terms of its opportunities and constraints for facilitating a reflective process, in which student teachers can develop their reflective abilities and come to think about their science teaching in new ways. In using Schön's notion (1983) of framing and Lee and Loughran's (2000) reflective cycle to detect acts of reflection in the VSR interviews (see Figure 3), this study attempted to explore a specific approach to VSR. In addition to the reflective cycle, Mackinnon's 'clue structure' was applied to separate acts of reflection from justification statements. In Chapter 3 and Paper 3, these analytical frameworks are described in more detail.

4.5.4 Study 4 - Analysis of the three groups' *reflections* on teaching challenges

The fourth study is based on the same empirical material as the third study but with a different research focus and questions. Although the third and fourth studies focused on student teachers' concerns of teaching science, the fourth study focused entirely on student teachers' awareness of the challenges of opening up a particular science content to a particular group of learners by using the exhibition's affordances. Thus, it did not focus on the reflective process (e.g., reflecting in, on, and for action) as such. Drawing upon subject-specific didactics in science (Andersson, 2011; Kansanen, 2009) and Brousseau's notion (1997) of didactical situations, and the modified didactic model inspired by Nyman (2017), the study set out to examine the challenges student teachers experience when teaching science at the science center (Q5). Furthermore, what aspects of science didactics in these challenges becomes central in creating didactical situations (Q6)? The focus was on aspects of science didactics, including making science content accessible to their students, by using the exhibition environment and their knowledge of scientific content - as well as knowledge about the students' understanding of the science content.

The didactic tetrahedron (see Figure 2) was applied to illustrate the student teachers' challenges concerning their building of didactical situations. As mentioned in Chapter 2, the didactic tetrahedron is an illustration of a didactical situation (Brousseau & Balacheff, 1997), in which the student teachers orchestrate the interplay between the science content, the artifacts in the environment, and the students (Rezat & Sträßer, 2012). By using the tetrahedron, it was possible to foreground the relationships and surfaces coming into play and the student teachers' challenges with science didactics and, thus creating didactical situations in the teaching at the science center. However, the student teachers do not use the term didactical situations or science didactics in the interviews. These concepts are a way for the researcher to describe and analyze the challenges that student teachers experience in teaching specific science topics to certain age groups of students in the different exhibitions of the science center.

4.6 Quality aspects of the research

Qualitative methods concern how to characterize the nature of something systematically. They are contextual, subjective, and do not claim to be generalizable (Whittemore et al., 2001). Researchers within the qualitative research tradition try to characterize phenomena in ways that produce new meaning. The internal logic of such methods concerns the harmony between the research question, research assumptions, and the nature of the phenomenon, data collection, and analytical tools (Larsson, 2005). When applying variation theory as an analytical framework in the first study (Paper 1), the focus was on the student teachers' use of relevant variation to make objects of learning accessible for themselves (Booth & Hultén, 2003; Marton, 2015). The dimensions of variation that were opened in the student teachers' content-focused group discussions described the critical aspects discerned and the pattern of variation and invariance (contrast, generalization, separation, and simultaneity) used in the learning situation. In order to ensure the quality of the research, the analysis aimed to provide 'thick descriptions' (Geertz, 1973) capturing the essence of how and to what extent the student teachers created learning opportunities for particular objects of learning. In order for learning opportunities to be created, the dimensions of variation opened by the student teachers and the patterns of variation used needed to be related to the same object of learning (e.g., adaptation). With this said, the study applied the variation theory in a relatively unexplored manner, aiming to extend the horizon of variation theory as a lens through which to examine learners' potential for creating learning opportunities for themselves.

4.6.1 Trustworthiness

Lincoln and Guba (1985) introduced trustworthiness as an overarching criterion of validity in qualitative research. They suggested five alternative concepts for assessing qualitative studies: credibility, transferability, dependability, conformability, and authenticity. Credibility, which answers the question "Do the results of the research reflect the experiences of participants or the context in a believable way?" (Whittemore et al., 2001, p. 534). Transferability corresponds to external validity and answers the question: can the findings be generalized or transferred to other contexts or groups? (Elo et al., 2014). Then there is dependability, which "refers to the stability of data over time and under different conditions" (Elo et al., 2014, p. 2). The last two concepts are conformability and authenticity, of which the first one refers to how well two or more independent researchers agree about the precision of correctness, relevance, or meaning in the study. Authenticity refers to how well the researcher can show a span of realities impartially and faithfully (Elo et al., 2014). In the following sections, the approaches to minimize possible limitations to the research trustworthiness are discussed.

4.6.1.1 Minimizing the limitations to credibility and authenticity

The primary technique for collecting empirical material was through video footage of each of the three groups of student teachers' planning meetings and science lessons at the science center. In addition to this method, audio-recordings of the VSRs with each group of student teachers were made. In these VSRs, video footage of the student teachers' science lessons was used to stimulate reflections about the teaching and practice as a whole. The student teachers were video recorded without the researcher's presence (except during set-up and video recording of their lessons) to minimize the threats to credibility and authenticity concerning the influence of video footage of the student teachers' planning meetings (e.g., avoid the risk of the video camera influencing the student teachers' behavior or making them less open). In the audio recordings of the video-stimulated reflection interviews, the student teachers were given autonomy to decide when to stop the video viewing and decide what they wanted to share with the group and the researcher. Thus, the student teachers themselves mainly governed the reflections that took place.

4.6.1.2 Avoiding conformability limitations

Although the video and audio recordings provided rich data, allowing for careful observation and documentation of situated expressed experiences within the educational context (Derry et al., 2010), it was central to avoid conformability threats. For example, to avoid making over-interpretations of the student teachers' articulated ideas and experiences, the research papers' co-authors analyzed the empirical material. The excerpts of the transcribed data and results were also presented in research seminars with scholars in the field. Another threat to conformability was the possible power relationships within the groups of student teachers, which could have influenced their willingness to articulate, share, and discuss concerns and ideas openly. This threat was more difficult to avoid and therefore needed careful consideration in collecting each set of empirical material.

4.6.1.3 Ensuring credibility

The video data of the student teachers' planning meetings and science lessons – as well as the audio recordings of the VSRs, were transcribed verbatim. During the analysis in all of the four studies, it was central to ensure credibility. Thus, it was carefully considered how wide or narrow the selection of units of the analysis would be. Too broad would have captured more than the discussions of a particular object of learning (see, e.g., study 1). Too narrow a unit of analysis would exclude essential meanings. Another threat to credibility, but also conformability concerned the interpretation, and description adequately represented the concepts in, for example, variation theory (e.g., dimensions of variation and patterns of variation) or theory of affordances (e.g., affordances, hidden affordances, and broken conventions). To avoid these kinds of limitations on credibility, recurring discussions with co-authors and independent scholars with the theoretical framework's experiences and fellow researchers in seminars were meaningful.

4.6.1.4 About transferability

Examining the possibilities for student teachers' knowledge developments in science and science didactics in an out-of-school science environment involved not only descriptions of the student teachers, but also in thorough and thick descriptions of the contextual character of the whole learning, teaching, and reflecting situations, such as the physical environment and the learning situation's social organization. Thus, a lack of a thick, and detailed description of the contextual character would limit the possibility to transfer the findings to other settings and groups, to which this thesis aspires.

4.6.2 Ethical considerations

Hammersley and Traianou (2012) describe why ethical and other decisions made by the researcher are dependent on the situated nature of the research context:

> The situated nature of practical decision-making within research makes clear that sound judgment about what it is best to do cannot be made simply by following instructions or applying rules. In this respect, and others, research is a form of praxis; in other words, it is an activity in which there must be continual attention to methodological, ethical, and prudential principles, what they might mean in the particular circumstances faced, and how to best act on those circumstances as a researcher. (p. 7)

Thus, no research study is the same, and the ethical considerations and decisions the educational researcher must make are closely linked to the research context, the different phases, methodologies, and situations within a research practice (Hammersley & Traianou, 2012; Tangen, 2014). In collecting empirical material through video footage of the student teachers' planning meetings, implementation of science lessons, and VSR interviews, the student teachers were given information about the research a couple of weeks before carrying out the course module at the science center. On the course module's introductory day at the science center (both in 2016), the cohort of student teachers were informed about the research once more and what participation would entail. Giving student teachers time to decide was an important factor in showing respect for their autonomy. Time also allowed the student teachers to think about the course module and what activities they would be involved in. The consent form (see Appendix, Chapter 9) handed to the student teachers at the first meeting included information about what activities (planning meetings, group reflection, implementation of lessons) would be video and audio recorded. It also included who would be doing the video footage, who would see them, where they would be used (professional meetings, research conferences, and researcher staff). The student teachers were also informed that they could withdraw their participation at any time. More than three groups of student teachers volunteered to participate, but three were selected (two groups preparing for primary school and one group preparing for secondary school).

In relation to obtaining informed consent from the student teachers, some ethical considerations were made. Researchers want study participants to understand information concerning their decisions about participation in research studies (Hammersley & Traianou, 2012), and even though the student teachers understood complex information, made decisions, and drew their conclusions, they all had different backgrounds, life experiences, and concerns. Consequently, they possibly interpreted the information provided in different ways. Despite these interpretive differences, they saw their participation as meaningful to themselves as student teachers and a way to contribute to research and teacher education development.

To make sound ethical decisions that take into account the student teachers ability to understand what is expected of them, what their participation will mean in practice, and for the larger group they represent, and how it will be used and shared was crucial. Therefore, it was important to be sensitive to the student teacher's feelings and different concerns about the research, not only in the phase of collecting empirical material (e.g., video footage and audio recordings) but throughout the entire research process and in the sharing of data. Thus, it was important to avoid making open public criticism of student teachers when sharing video footage and audio recordings, such as comparisons between them regarding personal characteristics. The risk of giving the student teachers a negative reputation would be non-ethical and could cause them harm and the group they represent (Comer, 2009; Derry et al., 2010). In this research, the goal has been to minimize harm to the student teachers and at the same time allow other researchers to review and reinterpret the video data to improve the quality of research.

5 RESULTS

In this chapter, a summary of the main results and conclusions from each of the four empirical studies is presented. These are then discussed in Chapter 6, in relation to the overall research aims and prior research.

5.1 Study 1 - Student teachers' *planning* meetings

The first study of the thesis (see Paper 1) set out to examine how student teachers jointly come to understand science ideas and principles, when planning science lessons in small groups. The empirical material encompassed video footage of the three groups of student teachers' lesson planning (1–3 meetings, in total 1.5–2 hours per group). The recording sessions took place in a classroom at the science center. By drawing on variation theory (Marton, 2015) and the framework of small-group discussions (Bungum et al., 2018), the study explicitly focused on the student teachers themselves as the primary agents for opening dimensions of variation of objects of learning, making learning science learning possible. In line with this focus, the study set out to answer the following research question: (Q1) *how and to what extent are opportunities for learning science constituted through student teachers' talk in small-group discussions?*

In the results, 21 distinct science content-focused discussions concerning different objects of learning – including ideas and concepts in science (e.g., gravity, adaptation, and decomposers in nature), but also physical phenomena in the exhibitions – were identified based on Bungum et al.'s (2018) framework of forms of small-group discussions (see Table 5). Furthermore, discussions were distributed across the different forms of small-group discussion as shown in Table 5.

Table 5. The table shows an overview of the character of the identified content-focused group discussions and how many that were identified in each group.

Frequency of different small-groups discussions	**'Life in space group'**	**'Ecosystems group'**	**'Evolution group'**	**The patterns of variation and invariance used in opening dimensions of variation, and their density in relation to the characters of small-group discussions**
Independent statements	2			Other patterns than contrast was limited The density of patterns was low.
Independent statements with elements of confirmatory talk	2	1		
Confirmatory talk	2			
Confirmatory talk towards cumulative talk	1	4	2	Both the patterns contrast and generalization were created Patterns of variation appeared more frequently
Cumulative talk		1	3	
Cumulative talk towards exploratory talk			1	All the patterns, contrast, generalization, separation, and simultaneity were created. The density of patterns was also high
Exploratory talk			2	

As shown in Table 5, the discussions in the 'Life in space group' mainly moved from independent to confirmatory talks, which meant that the student teachers were not building on each other's comments and viewpoints, allowing for taking the discussion of the object of learning further. In this group, dimensions of variation were opened, but the density of patterns of variation and invariance (e.g., contrast and generalization) was low. The discussions in the 'Ecosystems group' on the other hand, were mainly confirmatory talks, moving towards cumulative talks (see Table 1), which indicated that they went from repeating or confirming what had been said to building on each other's utterances and constructing a joint body of knowledge accumulated by individual contributions. In these discussions, the patterns, contrast, and generalization were the most frequent patterns. The content-focused discussions moved even further in the 'Evolution group', from cumulative to explorative talk, which involved asking questions, testing ideas, comparing it with other similar or different situations, and presenting different views of the object of learning. In addition, all of the patterns of variation and invariance (contrast, generalization, separation, and simultaneity) were present in these discussions, and the density of patterns was also higher than in the other two groups. This group also showed an increased ability to arrive at more complex and relevant understandings of the objects of learning they discussed during lesson planning.

For student teachers to arrive at a shared understanding of objects of learning when discussing them in small groups during planning of science lessons, they had to take on an explorative approach. For example, to engage critically with each other's ideas and make a joint consideration of statements and suggestions that may be challenged to finally reach a decision or agreement on a shared understanding. By doing this, a higher density of particular patterns of variation was created, and thus opened relevant dimensions of variation and invariance, enabling new ways of understanding an object of learning. These results are in accordance to Booth and Hultén (2003) and Bungum et al. (2018), who found that in order for learners to arrive at a shared understanding of an object of learning, learners are dependent on each other’s contributions in terms of questioning, agreeing and disagreeing with a given argument, but also comparing, isolating details and problematizing. In contrast to the student teachers in the ‘Evolution group’, who had more years of education in one or more disciplines of natural sciences, the student teachers in the ‘Life in space group’ and the ‘Ecosystems group,’ showed a more limited ability to arrive at a common relevant understanding of objects of learning.

5.2 Study 2 - *Implementation* of the topic ecosystems in the living rainforest

In the second study of the thesis (see Paper 2), the empirical material encompassed video footage of the ecosystems group's two 30 minutes science lesson(s) with school students in the living rainforest exhibition. The empirical material also included the group’s written lesson planning and lesson script in addition to the video footage. By drawing upon the theory of affordances (Gibson, 1986), Bruner’s notion of narrative-making (1991), and the model of MER (Tsui & Treagust, 2013), the second study set out to answer the following research questions: *what affordances of the presented living rainforest do the student teachers act upon in constructing the curriculum topic ‘ecosystems’?* (Q2*), Furthermore, in what way does the living rainforest appear to afford such teaching actions?* (Q3)

In this study, three different types of narratives emerge, indicating different ways of acting upon the living rainforest in teaching about ecosystems. The first narrative is about the constraints of the real-world objects (living and non-living objects in the rainforest exhibition) for teaching about the micro and sub-micro world. In this narrative, real-world objects, for example, a green plant, was used to represent processes on the sub-micro level (e.g., the roles of carbon dioxide, water, glucose, and oxygen). No other modes of representations (e.g., objects, animations, drawings, figures), except for gestures were used to help the students to translate between the (invisible) sub-micro world (reactants and products in photosynthesis) to the macro world (real-world objects such as a green plant).

The second narrative had also to do with the constraints of the rainforest exhibition. To compensate for missing communities, but also to compensate for the lack of representational tools, the student teachers 'placed' action opportunities in terms of 'imagined' real-world objects in the living rainforest. An example is the 'placing' of an opportunity to observe fungi on a piece of ground. In this situation, the students were asked to search for the organism, although it was not possible to observe. Another example is when the students were asked to look for oxygen-producing algae in an aquarium, although no algae could be seen. Both examples indicate an aspiration of pursuing the planned curriculum, which had the character of 'order of content', in line with the formal curriculum (Doyle & Carter, 2003). However, the living rainforest appears to constrain these narratives of teaching.

The third identified narrative emerged only in glimpses and differed from the previous two. Instead of following the planned 'order of content', this narrative was co-constructed by the student teachers and the students through 'in-the-moment' observations with the rainforest's macro representations' affordances. That is, the real-world objects, visible to the naked eye. This narrative emerged in connection with a pause in the planned 'order of content' curriculum. For example, while waiting for all the students to gather in the 'canyon' (a separate net fence with small birds and butterflies), the student teachers attended to the present students' observations and questions about the butterflies flying around them.

The results demonstrate that the student teachers in the 'Ecosystems group' struggle to make public the micro and the sub-micro world when moving from real-world objects of the living rainforest to the abstract verbal mode of representation (Tsui & Treagust, 2013), influenced by their curriculum narratives (Doyle & Carter, 2003). The results highlight the lack of representational tools to make visible the micro and sub-micro world in these teaching-learning situations. They also point to the lack of perceiving the constraints of the 'presented' context (Braund & Reiss, 2006) in terms of its incompleteness of key communities central to an ecosystem, and other modes of representations making the micro and sub-micro world visible (e.g., signs, models). When the student teachers left the 'order of content to be delivered', a co-constructed narrative occurred. In contrast to the dominant constructed curriculum narrative, this placed the students more in the center of the teaching situation. In the co-construction of narrative, the student teachers were responsive to the students 'in-the-moment' observation and experiences and took advantage of those as 'teachable moments' (Hyun & Dan Marshall, 2003). See an example of this, in Paper 2, excerpt four.

5.3 Study 3 - *Reflections* on science teaching at the science center using

In the third study of the thesis (see Paper 3), the empirical material encompassed VSR interviews with each of the three groups of student teachers, two months after the course module at the science center. The interviews were audio-recorded, a total of about two hours per group and took place at the university. Drawing upon Schön's (1983) model of framing, and by using the reflective cycle model (Lee & Loughran, 2000; Mackinnon, 1987) as an analytical tool, the study aimed at examining its opportunities and constraints for facilitating a collective reflective process in which student teachers could develop their reflective abilities and come to think about their science teaching in new ways. The following research question was formulated: *how can video-stimulated reflection interviews with student teachers can be designed in order to facilitate a reflective process* (Q4).

The results demonstrate that the VSR approach facilitated a reflective process, in which the student teachers articulated their concerns and recognized them as problematic situations. These were shared and discussed in the group. The results also demonstrate that the video viewing of the second lesson in relation to the first made student teachers become aware of different aspects of a problematic situation. This allowed further reconsiderations of initially framed problematic situations. In these situations, the reflective process moved into box II, in the reflective cycle, see Figure 3. The variation in terms of seeing new aspects in the video footage of the second lesson, and seeing these aspects together with the initially framed problematic situations in relation to the whole (science lesson), seemed to provide a shift in perspective. For example, shifting from seeing the situation from a teacher-centered perspective to a student-centered, or seeing problematic situations from another's perspective or from one's own experience of being a young learner was observed. In addition to these results, the reflective process in the three groups did not move into a real resolution, box III.

In order for the student teachers to resolve a problematic situation, they needed not only to engage in acts of reframing, but also to draw real conclusions about their own pedagogical efforts in relation to their students' learning. However, to draw conclusions about what the students learned was constrained by the short time they had with the students and the fact that they were not given the opportunity to assess the students' knowledge before and after the lesson at the science center. These results accord with earlier observations by Mackinnon (1987). Although the student teachers did not solve the reframed problematic situations, the specified approach to VSR enabled the student teachers to gain a better understanding of the affordances (opportunities and constraints) of the science center environment, the relevance structure and didactical situations in relation to their own pedagogical efforts.

In sum, the VSR approach facilitated reflection *on* and *for* possible future possible actions in practice for all three groups of student teachers, which is a central ability that student teachers need to learn (Beauchamp, 2015). In addition, the VSRs enabled a reflective space in which the student teachers' concerns were put in the center, allowing them to share, discuss, 'step outside', and see their own and fellow student teachers' practice from 'a distance'.

5.4 Study 4 - *Reflections* on challenges related to science didactics

In the fourth study of the thesis (see Paper 4), the empirical material encompassed the same VSR interviews with each of the three groups of student teachers. In contrast to the third study, this study focused entirely on the science-specific didactics of student teachers' challenges of teaching and not on reflection as such. In line with this focus, this study examined student teachers' challenges of creating didactical situations, in which they enact the interplay between the science content of teaching, the artifacts in the exhibitions (living and non-living objects), and the students. By using a thematic analysis, the modified didactic tetrahedron inspired by (Nyman, 2017), and drawing upon the notion of didactical situations (Brousseau & Balacheff, 1997), the study set out to answer the following research questions: (Q5) *What are the challenges student teachers experience when teaching science at the science center?* (Q6*) Furthermore, what aspects of science didactics in these challenges becomes central in creating didactical situations?* In the results, four challenge themes related to specific aspects of science didactics emerged in the analysis of the VSRs: (1) The influence of artifacts, (2) knowledge of students' understanding, (3) making scientific content accessible, and (4) the complexity of asking questions. In the first theme, the influence of artifacts, the student teachers became aware of the influence of the environment's artifacts (living and non-living objects) on teaching-learning situations. Sometimes they contributed to (as representations) or disrupted the student teachers' planned content of science teaching. As unplanned artifacts 'entered the scene' and drew attention, they implicated scientific content other than what the student teachers initially had planned.

The second theme concerned the lack of knowledge about what the students understand of the science teaching and the difficulty of teaching at a level appropriate to the students' age group. The theme also concerned the lack of knowledge about the students' understanding of the purpose of an activity or that the learners' understandings differed from their own.

The third theme concerned the student teachers' awareness of their shortcomings of explaining science concepts to the students. Regarding this challenge, two aspects were salient. Firstly, relating science concepts to each other in the teaching situation, and second, being consistent in the use of concepts, secondly in the 'Ecosystems group', these concerns about what scientific concepts to use were discussed in relation to the science didactics in the course literature (see, e.g, Andersson, 2008).

In the fourth theme two aspects of questioning dominated. The first had to do with the difficulty of asking questions to direct students' focus toward the scientific content, enabling them to reflect on the scientific content, and making them aware of their learning. The second aspect concerned the difficulty of asking the right kind of questions at the right time - as well as being precise about how the question should be worded. In connection to these challenges, the student teachers referred to their difficulty of interpreting and integrating theories of science didactics with practice.

The results demonstrate the need to develop responsiveness and adaptability to (unfamiliar) artifacts and to the students' interest. However, the ability to adapt entails the ability to improvise and make decisions in the 'midst' of teaching. Even though the environment provided significant 'wow' factors, contributing to the students' interest and curiosity, it became evident that it did not always connect to the student teachers' didactic aims. Consequently, the student teachers had difficulties turning these 'wow' moments into a didactical situation (Brousseau & Balacheff, 1997), facilitating students' learning of the intended content of teaching. The student teachers challenges with using science concepts is consistent with earlier research that demonstrates that student teachers' subject knowledge in science plays a significant role in building didactical situations in which students can make ideas and principles in science their own (see e.g., de Jong et al., 2011; Rollnick et al., 2008; Zetterqvist, 2003). In addition, the lack of knowledge of how to ask questions that ascertain how the science content of teaching appears to the students – as well as too little knowledge of the students' prerequisites and experiences, constrained the student teachers' opportunities to create didactical situations. That is, their ability to orchestrate an interplay between the students, the artifacts as representations, and the particular science content (Rezat & Sträßer, 2012). Consequently, the student teachers struggle with building a relevance structure for their students that indicates what the teaching is aimed at, what it requires, and where the activity will lead (Marton & Booth, 1997).

The challenges concerning making the science accessible for their students, knowing what the students understand, and asking questions are not in any way unusual. Student teachers face these challenges as well in the classroom. However, the challenge with the affordance beyond the classroom concerning objects/artifacts in the environments differs from the classroom. As opposed to the classroom, the science center environment is an unfamiliar setting, less controlled and controllable with which the student teachers have difficulties.

6 DISCUSSION

The work in this thesis aimed to learn more about the opportunities and constraints on student teachers' learning of science and teaching science when in small groups they plan, implement, and reflect upon teaching at the science center. Furthermore, it aimed to identify what becomes critical for teacher educators and science center educators when facilitating experiences that enable student teachers to learn, teach, and integrate science didactics theories in an unfamiliar, resource-rich, and multi-sensory environment. This thesis aspires to understand how the science center can be a critical space for student teachers' development. The results from the four studies point to both opportunities and constraints for student teachers' development and in so doing highlight aspects of science didactics that need to be addressed by teacher educators. In the following, these aspects are discussed in relation to prior research and in relation to implications for teacher education, i.e. what becomes educationally critical from a teacher education perspective. The discussion will also suggest approaches that are required to fill these emerging gaps in the provision of teacher education concerning science and science didactics in an out-of-school science context. However, before this discussion, some reflections on the didactic tetrahedron and the VSR approach taken in this thesis are presented.

6.1 The potential of the didactic tetrahedron on macro and micro level

On a higher level, the modified didactic model inspired by Nyman (2017), and initially developed by Rezat and Sträßer (2012) illustrates the aims of this thesis and foregrounds the four sub-studies and their respective foci and specific research questions. In this way, the model provides a useful framework for the research as a whole. On a lower level, the didactic model and its relationships constitute areas for analyzing (Nyman, 2017) didactical situations (Brousseau & Balacheff, 1997) in the student teachers' science lessons. Hence, on this level, the didactical model functions as an analytical tool for understanding the web of aspects at play in science didactics that student teachers need to handle in their practice of planning, teaching, and reflecting upon teaching in the multi-sensory environment. The fourth vertex in the tetrahedron adds a new dimension to the didactic triangle and the didactical situation that takes into account the influence of the resource-rich environment on teaching-learning situations. In addition to the model's contribution as a framework and analytical tool, it can help student teachers - as well as teacher educators to become aware of and work with the relationships between themselves, the students, science content, and artifacts in planning and communicating science didactic issues of teaching and learning science (Wickman, 2018).

With that said, it is important to point out that the model is a simplification of teaching-learning situations. The didactic tetrahedron model illustrates the complex system of didactical situations, including social, institutional and cultural factors. However, the model is not sufficient alone to be used as a didactic tool, but must be supplemented with didactic questions, see Chapter 1, Introduction. Finally, in the way the model is used in this thesis, the highlighted artifacts are ‘shared’ by the students and student teachers and used as representations for particular science content. However, there are many artifacts (such as objects, living animals, and plants) in the science center environment that call for attention, which makes the sharing of one and the same artifact a challenge for the student teachers and their students in the teaching-learning situations. It may therefore be debatable whether an artifact is really ‘shared’ in some of the teaching-learning situations. Not literally shared as in seen, identified and used, or shared in that it is noticed or shared, but whether an artifact is shared in that its affordances are seen but differently translated.

6.2 VSR as a way to facilitate student teachers’ reflective process

The VSR interviews used in this thesis research, allowed student teachers to reflect on their experiences and consider future actions in their practice. Thus, the VSR not only served as a method for collecting empirical material, but also as a collective space for student teachers to articulate and share concerns, and frame and reframe problematic situations in their teaching. In addition, the elapsed period between the course module assignment at the science center and the VSR interviews enabled the student teachers, in light of their teacher training, to step 'outside' their practice and view it from a 'distance.’ This opened up the possibility of seeing one’s own and fellow students’ pedagogical efforts in another way that they would not be able to do otherwise. However, the reflective cycle analysis (Lee & Loughran, 2000) showed that in order for the student teachers to draw real conclusions of the students’ learning and resolve problematic situations (Mackinnon, 1987), they would have needed better knowledge about their students’ experiences and understanding of the presented science content. This indicates that the relationship between the student teachers and their students is central in order for the student teachers to create didactical situations and build relevance structure that takes its point of departure from the students’ ways of understanding the world (Lo, 2012; Marton, 2015). In addition to these constraints of moving the reflective process into resolution in the reflective cycle (see Figure 3), VSR requires a skilled facilitator (researcher/teacher educator). In the VSRs, a major challenge was to find the balance between allowing student teachers autonomy (e.g., deciding when to stop the video viewing and what concerns to share and discuss), and on the other hand triggering reflection that involved reframing, shifting perspective, and imagining future possible actions in practice. Hence, further investigations are needed to learn more about the affordances of the facilitator and how to design well-thought VSRs that enable student teachers to create a reflective space together to develop as science teachers. Student teachers need time to reflect together upon their experiences in general. This thesis suggests that VSR should be integrated more into student teachers' preparation and used regularly.

6.3 Learning science and reflecting on science teaching in small groups

Throughout the practice of planning, implementing, and reflecting upon their science lessons at the science center, the student teachers worked in small groups. The results indicate that working, discussing, and reflecting in small groups did not only open up an understanding of specific science content on a collective level, but created a space for collective experiences where student teachers could shift perspective on their teaching, and imagine how they would improve their practice (Beauchamp, 2015; Dillon, 2011). Furthermore, the key for arriving at a shared understanding of an object of learning or a problematic situation seems to be the ability to adopt explorative talk in the small-group discussions (Bungum et al., 2018). It is not about student teachers producing new information through exploratory talk, but that they construct new meanings from the information, which is made available to them in the group (Booth & Hultén, 2003; Marton, 2015). By adopting an explorative approach in small-group discussions and reflections, whether it is towards an object of learning or a problematic situation in teaching, it seems to be critical to engage with each other's concerns, viewpoints, and jointly consider suggestions and discerned aspects to reach a shared understanding (Bungum et al., 2018; Marton, 2015). Hence, in line with Marton (2015), student teachers need to learn to discern aspects of problematic situations in teaching themselves in order to view them in new ways. Schön's (1983) notion of reflection as a process of framing and reframing, overlaps with the idea in variation theory that learning is about seeing and becoming aware of differences, and to bring those different aspects together to a more powerful understanding than before (Bowden & Marton, 1999; Marton & Booth, 1997).

A teacher educator/researcher that is present during a VSR can support and use cues to facilitate student teachers' exploratory approach (framing and reframing) to problematic situations and view them in other ways. However, student teachers in small-group discussions who do not have access to an external source (e.g., a teacher educator), are constrained by their ability to adopt such an exploratory approach. It is difficult for them to construct new meanings based only on the information made available to them in the group. These findings point to the need for teacher educators to become aware of conditions that constrain or facilitate the construction of new meanings and reflective processes in small groups. By simply observing a discussion among student teachers, teacher educators can detect how objects of learning and problematic situations in teaching are approached, and how understanding is progressing amongst the student teachers. Then, teacher educators will be able to decide the next stage of learning, depending on the progress that has been displayed.

6.4 Education of attention and uncovering affordances of a presented environment

From the work in this thesis, it is evident that affordances of the science center environment, both in terms of opportunities and constraints, extend beyond the affordances of the classroom. Firstly, the results imply that in order to perceive the affordances of the living rainforest for teaching about ecosystems, the student teachers would have needed more time, and tools, to uncover the affordances of the exhibition's narrative and artifacts (Achiam et al., 2014), since they may be hidden and cannot be perceived directly. Secondly, for the student teachers to discover and capture teachable moments (Hyun & Dan Marshall, 2003), they need to develop adaptability and responsiveness to the dynamic environments' affordances and to the students' interests and observations. Thirdly, in the same way that student teachers need to develop their ability to 'read' nature in the outdoor setting (Magntorn & Helldén, 2007), they need to develop a similar ability to 'read' a presented environment (Braund & Reiss, 2006) to reveal hidden opportunities and constraints for teaching and learning about particular topics like 'ecosystems.' However, to 'read' nature, which implies the ability to identify plants and animals in an ecosystem and connecting them to the environment, is a challenging task in a presented environment, such as the living rainforest in focus here. Not only because of the incompleteness of the presented rainforest in terms of missing communities (e.g., insects, microbes, fungal species, etc.) that are central to an ecosystem (Nyberg et al., 2019), but because animals, plants, and abiotic factors are exhibited in ways that do not occur in natural settings.

In order to make relevant decisions of what to utilize as representations in teaching about particular science content to a particular group of students, it is required that teacher educators and science educators make the teachers aware of the material-rich and multi-sensory aspects of the exhibitions and of unexpected events. In the words of Gibson, it is about facilitating an “education of attention” (Gibson, 1986, p. 254) that involves unravelling the [pedagogical] affordances of the exhibitions. These affordances might offer another kind of narrative-making in teaching (Prins et al., 2017) that takes a departure from the available opportunities and perhaps lead to another kind of interpretation of the formal curriculum than ‘order of content to be delivered’ (Doyle & Carter, 2003). ‘Education of attention’ must also involve development of responsiveness to the students ‘in-the-moment’ observations (Wallace & Priestley, 2017) of the exhibition’s real-world objects (visible to the naked eye). The student teachers should be encouraged to make ‘diversions’ from the lesson scripts, capturing ‘teachable moments’ (Hyun & Dan Marshall, 2003), or as Schön (1983, 1987) describes it, ‘in-action’ decisions together with their students. Finally, student teachers will need support in creating and using narratives in their teaching of science (Bruner, 2003; Prins et al., 2017). To enable this, Bruner (2003) suggests that student teachers and their students need to view science-making as a generator of knowledge and representations, created from a particular perspective. By this way of viewing the scientific process, science teaching and learning in the classroom can be approached as a co-construction of science ideas and principles – a co-construction of curriculum narratives (Remillard, 2005).

6.5 The issue of assessment and interpreting the curriculum

While practicing together with fellow student teachers can enable critical friendship and potential development (Beauchamp, 2015), there is also an undercurrent of assessment present. It seems that, to different degrees, the student teachers viewed the formal curriculum too rigidly and interpreted it as a script to organize science rather than to organize teaching. This is especially evident in the ‘Life in space group’ and the ‘Ecosystems group’. These results point to the issue of interpreting the formal curriculum. It may be that assessment is influencing how the student teachers interpret the formal curriculum, and how they construct the narrative in teaching, promoting a teacher-centric rather than student-centric approach. The pressure to pass examinations to become a teacher in the future is maybe an expression of how the student teachers perceive teacher education. If assessment of student teachers’ lesson plans and teaching to students is removed, it may release the pressure on them to ‘perform well’ and construct curriculum narratives as ‘telling’ science (Brown et al., 2013). This would allow for co-constructed narratives, affording ‘teachable moments’ based on the students’ in-the-moment observations. The ‘teachable moments’, could, in turn, be connected to the formal curriculum. Furthermore, these moments would allow a relevance structure that takes departure from the students’ interests (Fors, 2012; Marton & Booth, 1997).

6.6 To make public the micro world of science

Something that becomes clear in this thesis is the ability of the student teachers to use, and develop, representational tools to make public elements of the micro and sub-micro world. It appears that the material-rich exhibitions convey an abundance of representations to use in teaching. However, this conviction is to some extent an illusion. In the presented living rainforest, certain opportunities to create observations are available, while others are constrained. For example, the missing representations of key communities central for an ecosystem, and the lack of other modes of representations (signs, diagrams, models) constrains making the micro-world public. Furthermore, the student teachers' unfamiliarity with the science center, as a place for teaching and learning, may constrain their courage to bring in representations that are missing, but that could assist the necessary translations between the macro- and micro-world (Tsui & Treagust, 2013). These results indicate that it is important for teacher educators to facilitate student teachers' experimentation with representational tools in their practice of planning and implementing science lessons so that they can make public the invisible micro world.

6.7 The issue of integration of theory in practice

The planning, implementing and reflecting upon their science teaching at the science center, provide an opportunity for the student teachers to integrate theories of science didactics in practice (Hammerness & Klette, 2015; Jenset et al., 2018). However, this thesis raises important questions about how such an integration can be made successful. As the results indicate, the course module at the science center offers student teachers the opportunity to integrate their knowledge of the environment's affordances as representations (context) with knowledge of science content (what), theories of science didactics (what and how), and the curriculum (what) into narratives working (how) *in situ* with the students (to whom). However, the results show that this integration work is a great challenge to the student teachers. During planning of science lessons, the student teachers need to interpret the formal curriculum, handbooks in science didactics, science literature and the science representations in the science center exhibitions. In this process, their prior experiences and views of science teaching, science content, the exhibition environment, and students will influence their interpretations. This, in turn, will affect their planning and implementation of science lessons, as well as how they reflect on teaching. Thus, the issue of integration is also an issue of interpretation and these are central aspects that need to be made visible, to both the student teachers themselves, and the teacher educators. If more time and space for iterative experiences of experimentation and reflection were allocated in student teachers training, these issues could perhaps be addressed in thoughtful ways. VSR can be one way to provide this space for reflection on the critical issues of integrating knowledge of science didactics from coursework and teaching experiences into practice. However, teacher educators need to contribute with "pedagogies of enactment to our existing repertoire of pedagogies of reflection and investigation" (Grossman et al., 2009, p. 274). In line with Sjöström (2018), the results in this thesis suggest that in order for science didactics to be relevant to student teachers and their future practice in out-of-school science environments such as the science center, it needs to connect to teaching practice and the specific affordances offered by the "presented contexts" of the science center environment. This thesis shows that the integration of field practice in an out-of-school science environment, like the science center in teacher education makes visible future science teachers' concerns and needs.

6.8 Limitations

The qualitative studies in this thesis can be considered as small case studies in a specific context, which could be seen to preclude generalizability on a larger scale. Furthermore, the research in this thesis does not claim to measure the student teachers' learning. Instead, it points to the possibilities of developing knowledge when practicing planning, teaching (to real students), and reflecting upon practice within the contexts of an out-of-school science environment. Notwithstanding these limitations, this thesis certainly adds to the understanding of the out-of-school science environment as a critical space for science [teacher] education. The study of student teachers' practice of planning, implementing, and reflecting upon their teaching in the science center exhibitions in small groups, has shown how complex such environments are for science education and indicates further approaches are required to prepare science student teachers in subject didactics. Although the current research is based on a small sample of participants and focuses on particularities of their practice, it sheds light on how teacher educators, and science educators, can facilitate opportunities for student teachers to develop knowledge that is critical within teachers' professional field of science didactics.

6.9 Final reflections and further research

It is evident that the science center environment affords multisensory experiences beyond the more teacher-controlled setting of the classroom, presenting contextual and didactical challenges but also possibilities. The results may help us understand how we can educate student teachers to adapt to affordances in these environments and respond to their students 'in-the-moment' observations and interactions. In addition, how they can capture 'teachable moments' and build a relevance structure for their students. The student teachers' need of how to build a relevance structure is overlooked in teacher education. Recurrent activities are needed where the student teachers can practice their ability to create a relevance structure (Lo, 2012; Marton & Booth, 1997). In addition, they need more experience in less controllable environments like the science center. Such experiences will make student teachers more likely to utilize these presented contexts – as well as outdoor environments (e.g., lakes, parks, etc.) in their future practice as science teachers. However, it requires practice and deliberate reflection on how to create didactical situations and build relevance for the learners. This thesis supports the idea that collaborations between the out-of-school science environments and teacher education is a fruitful way to connect coursework with practice and vice versa. Overall, this thesis strengthens the idea of an out-of-school science environment such as the science center, as a critical space for science [teacher] education.

This research has raised many questions in need of further investigation. One question concern teacher educators' and science educators' development of didactical situations for student teachers when implementing field practice at a science center such as the course module reported on in this thesis. In their work, they may emphasize different areas of the didactic tetrahedron (see Figure 2 in Section 2.4). The science educators, who work daily in the exhibitions using artifacts as representations in interactions with diverse learners, are well acquainted with the science ideas and principles linked to the artifacts. The teacher educators on the other hand, are less familiar with the exhibitions, the artifacts, and the science ideas they represent. However, they may have a deeper knowledge of the science subject connection to the curriculum, theories in didactics, basic educational science, and the student teachers' progression as science teachers. These differences in perspectives and approaches to the didactic tetrahedron, and thus the creating of a didactical situation, will emphasize different aspects of science didactics. It would therefore, be interesting to investigate how the didactic model can make visible the teacher educators' and the science educators' perspectives and approaches to didactical situation for the student teachers. What aspects of science didactics foregrounded in the didactic tetrahedron are focused on? Furthermore, how can the didactic model be a support and tool for both categories of educators when creating these didactical situations for the student teachers?

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9 APPENDIX

The appendix contains the consent forms used for the participants in the study.

9.1 Consent form for student teachers

Samtyckesblankett för lärarstudenter gällande medverkan i forskningsstudie om lärande och undervisning i naturvetenskap

Bakgrund

Jag heter Alexina Thorén Williams och jag är doktorand i naturvetenskap och teknik med inriktning mot utbildningsvetenskap. Mitt forskningsintresse handlar om lärarstudenters utveckling av ämnesdidaktisk kompetens i en lärmiljö utanför skolan, som Universeum science center. Denna studie syftar till att få kunskap hur jag kan göra en bra kvalitativ studie (samla in data med video inspelningar och intervjuer) och vad som kan vara intressant att titta närmare på i min fortsatta forskning.

Allt arbete inom studien kommer att ske i enlighet med Personuppgiftslagen (1998:204)1. Inspelningar kommer att förvaras på sätt som innebär att obehöriga inte kan få tillgång till dem. De personer som medverkar på videoinspelningarna kommer att vara anonyma i den rapportering som kommer ut av projektet. Namn kommer att ändras till fiktiva namn i de texter som publiceras av projektet. Om bilder från videoinspelningarna används vid rapporteringar kommer även de att anonymiseras så att personerna inte är möjliga att känna igen.

Filminspelnings- och intervjutillfällen

1. Intervjua er vid lämplig tidpunkt under er introduktionsdag på Universeum .
2. Filma ett eller flera av era planeringsmöten på Universeum.
3. Filma ert inbokade möte med Universeums handledare.
4. Filma ert undervisningsmoment (2*30 min) med inbjudna elever.
5. Intervjua er en tid efter undervisningsmomentet i en sk Stimulated recall. Det innebär att vi tillsammans tittar på den videoinspelade undervisningen under intervjun.

Ni får väldigt gärna själva spela in era övriga möten där jag inte kan vara med. Om ni har frågor eller andra funderingar, tveka inte att höra av er till mig. Ni kan när som helst avböja vidare deltagande i forskningsstudien

E-post: alexina.thoren.williams@gu.se

Mobiltelefon: xxxx-xxxxxx

Med vänlig hälsning, Alexina Thorén Williams

9.2 Consent form for students consent form for students and guardians

Samtyckesblankett för elever och föräldrar gällande medverkan i en forskningsstudie om lärande och undervisning

Till elever och föräldrar på x skola.
Under besöket på Universeum den xx kommer en forskningsstudie att genomföras. Studien genomförs av Alexina Thorén Williams, forskare vid Göteborgs universitet och pedagog på Universeum. Studien syftar till att studera lärarstudenternas undervisning av skolklasser i Universeums olika utställningar.

Studien innebär att lärarstudenternas undervisning av eleverna filmas och inspelningarna kommer sedan att användas i forskning med fokus på lärande och undervisning i naturvetenskap och teknik. Videofilmningen kommer att ske när klassen deltar i lärarstudenternas undervisningsmoment (2 gånger 30 minuter) på Universeum den x/x. Allt arbete inom studien kommer att ske i enlighet med Personuppgiftslagen (1998:204)1. Inspelningar kommer att förvaras på sätt som innebär att obehöriga inte kan få tillgång till dem. De personer som medverkar på videoinspelningarna kommer att vara anonyma i den rapportering som kommer ut av projektet. Namn kommer att ändras till fiktiva namn i de texter som publiceras av projektet. Om bilder från videoinspelningarna används vid rapporteringar kommer även de att anonymiseras så att personerna inte är möjliga att känna igen.

Göteborg 2016-xx-xx
Kontaktperson vid frågor eller funderingar:

Alexina Thorén Williams (forskare)	Viktoria Åman (Pedagog Universeum)
Alexina.thoren.williams@gu.se	viktoria.aman@universeum.se

Deltagandet i videoinspelningarna är frivilligt.
Meddela i talongen nedan om du vill att ditt barn får delta eller inte.

_ _

□ Ja, jag samtycker till att mitt barn deltar i studien. Inspelningarna får användas i universitets forskning med fokus på lärande och undervisning.
□ Nej, jag vill inte att mitt barn medverkar i videoinspelning.

Datum______________________

Namn (elev):______________________________Vårdnadshavare: ________________________

Vårdnadshavares
Underskrift:____